JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA.
FOR THE
PROMOTION OF THE MECHANIC ARTS.

VOL. LXV.] FEBRUARY, 1873. No. 2

EDITORIAL.

ITEMS AND NOVELTIES.

An Improved High Pressure Alarm.—At the recent exhibition of the American Institute of New York, amongst the numerous mechanical novelties presented for public inspection was the ingeniously constructed alarm herewith illustrated and described. The instrument was patented during the last year, by Messrs. Jewell & Steele, of Brooklyn.

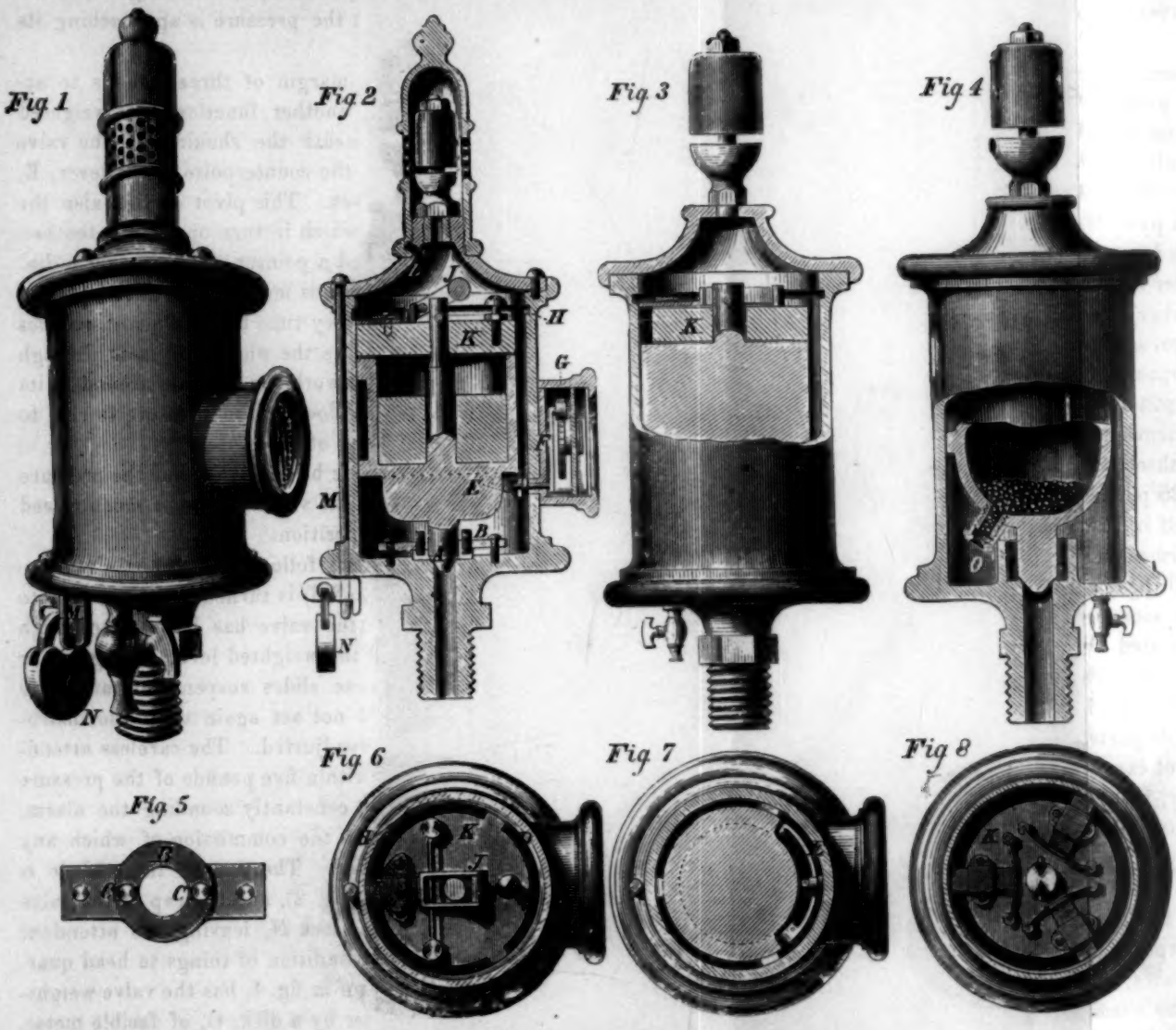
In the accompanying plate, A (Fig. 2) represents the valve, which is conical in shape and expanded above, to form a hollow chamber into which lead can be poured to weight it, or, as is the case in Fig. 3, it can be cast solid. About the valve seat is the plate, B, shown in detail in Fig. 5, the lower side being presented to show the two ports, C, through these openings; when the valve is but slightly raised, enough steam escapes to prevent any further rising of the valve until a greater pressure has accumulated in the boiler. The size of the posts and the weight of the valve may manifestly be so regulated as to bring about this action at any desired pressure. For example's sake, suppose 30 pounds, with a margin of three pounds to the pressure which the engineer is allowed to carry in his boiler. When the first figure is reached, the steam escapes through the ports, C

(Fig. 5), passing up through the annular spaces D (Fig. 6), to the whistle to warn the attendants that the pressure is approaching its limit.

Should the engineer permit the margin of three pounds to accumulate, the instrument performs another function. A weighted lever (Fig. 7), rests with one end beneath the shoulder of the valve weight (Fig. 2). As the valve rises, the counterpoise of the lever, E, descends, turning the lever on its pivot. This pivot carries also the arm, F. This last carries a pawl, G, which in turn operates a toothed wheel, to the axis of which is attached a pointer, moving over a dial plate (Fig. 1). This pointer or tell-tale is moved over the dial a distance of one tooth in the wheel for every time the attendant reaches or exceeds the margin of pressure. As the wheel only acts through a portion of its arc, it is impossible to work the tell-tale around to its original position, by surreptitiously allowing the pressure to rise to the required height a sufficient number of times.

Again, if the margin of three pounds be exceeded, and the pressure is run up, for example, to 35 pounds, the valve will be so much raised as to permanently lock itself in that position.

This motion is accomplished in the following manner. On the inner side of the outer shell (figs. 2 and 6) is turned a groove, H, into which the slide I enters as soon as the valve has been raised high enough, the slide being operated by the weighted lever, J, (fig. 6), or by springs as in figs. 3 and 8. These slides suspend an auxiliary weight, K, which from that time will not act again until the instrument has been opened and its parts readjusted. The careless attendant now finds that he cannot carry within five pounds of the pressure he was permitted to employ, without constantly sounding the alarm, thus calling attention to his fault, for the commission of which any suitably severe penalty may be exacted. The cap of the whistle is locked on the inside by the screw L, (fig. 2), and the cap of the valve is securely fastened by the rod M and lock N, leaving the attendant no other resource than to report the condition of things to head quarters. Another form of the valve, shown in fig. 4, has the valve weighted with shot, confined in the chamber by a disk, O, of fusible metal. The valve in first rising would sound the alarm, when, if neglected, the increasing heat and pressure will heat the fusible disk to such an extent as to melt it. The shot escaping from the chamber, so lighten the valve that the alarm will thereafter sound at a steam pressure much below that which the engineer is permitted or

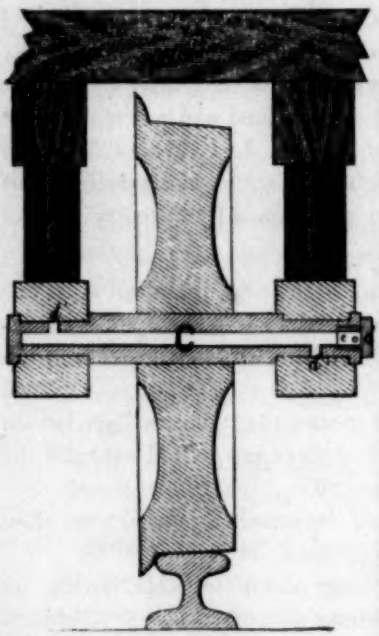


AN IMPROVED HIGH-PRESSURE ALARM.

desired to maintain. By the series of automatic movements here briefly described, the inventors have sought to surround the attendant with all the possible inducement to keep him always watchful and attentive to his duties.

A Self-Lubricating Axle.—The accompanying engraving illustrates a method of effecting the automatic lubrication of car-axles; designed and patented by Mr. Edward Williamson, a member of the Institute.

Each wheel is supplied with an independent axle, having its bearings in journaled boxes arranged between the ends of standards in the usual manner. The axle, C, is tubular, and has the inner end permanently closed, while the outer end is closed with a screw. The object of the hollow axle, is to afford within the wheel a reservoir of oil, which shall be supplied to the bearings automatically so long as the wheel is in motion. In order that the lubricant shall reach the bearing surfaces, it will be observed that the axle is provided with two openings, (*d d*,) at both ends and in opposite positions. The shank of the screw is made tubular and is supplied with an opening coinciding with that in the end of the axle. Another small aperture, *o*, in the screw permits the oil to be supplied to the reservoir, (C), by slightly loosening the screw.



The design of the inventor, as will already have been perceived by the reader, is to feed the lubricant upon the bearings automatically by centrifugal force; furnishing to the same a greater supply when the wheel is in rapid motion, and a diminished supply when the motion of the wheel is lessened, when less would be required.

The device is founded upon a simple and scientific principle, and if found to answer the purpose in practice, will become extremely useful.

Crank-shafts.—As many readers of the "Journal" are aware, the construction of this part of marine engines, especially when of the largest size, always has been attended with difficulties, as well during the finishing as the forging; the chief one, after a sound forging has been produced, being that of turning the three or more journals on it accurately in line with each other. In the endeavor to avoid these troubles, some engineers use what are termed "built-up crank-shafts," the cylindrical and flat parts, or "throws," being forged and finished separately, and then put together in the manner deemed best by the builder. The crank-shafts for the four pairs of compound engines for the vessels "Pennsylvania," "Ohio," "Indiana," and "Illinois," of the American Steamship Company, now building by the Wm. Cramp & Sons Company, were forged separately by Messrs. Seyfert, McManus & Co., and are being finished and put together at the Port Richmond Iron Works of Messrs. J. P. Morris & Co., in the following way, which it is thought will secure the parallelism of the three journals as nearly as can be obtained by ordinary tools of the machine shops:

The flat parts, or "throws," having been tool-finished all over, are bored, the hub to a shrinkage fit, for the shaft, and the eye for crank-pin roughed out to a diameter about half an inch less than that of the crank-pin.

After the key ways are cut nearly to size, the "throws" are heated and shrunk on the shafts, when the key ways are drifted out, and the keys driven hard and the ends dressed off.

Two half shafts (one "throw" and its attached journal), are then placed in a machine made thus:

A heavy cast-iron plate, 12 feet long and 4 feet wide, having its top surface planed true, is laid horizontally upon heavy imbedded timbers. Upon this are secured immovably four pillow-blocks, at proper distances apart; in line with these and beyond them are two temporary bearings, used for supporting a stiff boring-bar carrying a sliding cutter-head, which bores successively the four pillow-blocks in line.

The temporary bearings are then fixed immovably, in line with the four just bored, at a distance equal to that between the centres of the main journals and crank-pin. Two half shafts are then set in the four pedestals, with the "throws" towards each other, just as they are to be when completed, and the eyes in line with the bore of the

two temporary bearings or side pedestals, when the caps are screwed down hard.

A boring-bar is then passed through the eyes of the "throws," and placed in the side pedestals, and the crank-pin eyes bored out, the one on the right hand a little larger than that on the left. Before the fine finishing cut has been taken very careful measurements are made to test the parallelism of the bar and the shaft, and also to determine whether the shafts themselves are accurately in line, or have yielded under the strain of their own weight (14 tons) or the action of the working parts. The boring-bar and its bearings are then removed from the plate. The crank-pin is then turned to a shrinkage fit for each "throw," the end fitting the left-hand "throw" a little smaller than the other. This allows it to pass through the right-hand "throw" until the end brings up against the "throw" in which it belongs. A portable hydrostatic press is then placed so one plate bears against the left-hand "throw," and the other plate against the end of crank-pin, and distance-pieces fitted between the "throws." The pin is then forced into position, the key ways drifted out, and the keys driven hard and ends dressed off, and the shaft is ready to go into its place.

Small crank-shafts have been fitted in the same way by the Port Richmond Iron Works, with very satisfactory results.

These now spoken of being unusually heavy, a correspondingly increased care was observed in their manipulation, and it is believed that they are as near "true" as it is possible to make them. W. J.

New Style of Testing-Machine.—A new machine for testing the strength of metals, manufactured by Riehle Brothers, of the Philadelphia Scale Works, has been exhibited during the last few days to a number of scientific and practical mechanics and engineers. Some years ago the United States government made experiments which have served as the base for estimates of the strength that an iron beam may be expected to possess. It was found that an iron beam of uniform thickness of one inch fixed horizontally, with one end only supported, would break at a weight of from 507 to 980 pounds for American iron, and from 472 to 770 for English iron, the weight being applied one foot from the supported end. If both ends of the beam are supported, it will bear six times the weight that can be placed upon it with only one end fixed, and the strength of beams is in direct ratio with their width, in reverse ratio with their length and

in the ratio of the square of their depths. From the experiments thus made with perfect iron, the strength of materials was formulated; but practical experience showed that large forgings and castings were subject to blow-holes and honey-combs, which the most vigilant inspection would fail to discover—and these defects would lead to breakage at points of strain where theory said that the metal should bear the given pressure. The matter became of so much importance in view of the large number of iron girders used in modern buildings, that in New York a law was passed requiring an actual test of beams, girders, &c. The machine exhibited by Riehle Brothers is designed for testing practically the tensile strength of bridge bolts, wire and hemp rope, chains, &c., in any lengths, beside boiler plate and other materials, and also to test specimens of any substance by compression. It can be so arranged as to test the resistance of iron and stone columns by crushing, girders by transverse strain and any material by any strain, including torsion. The parts of this ingenious contrivance are so arranged that the weighing levers are at one end, and the power, which consists of a hydraulic pump and jack that run upon wheels along a horizontal track, is at the other end. The strain is applied by the pump and jack which are used to take up the slack, and not to determine the amount of tension, as in most other machines of this kind. The tension is found by means of the weights which are placed on the disk suspended from the beam, and an ordinary one-pound weight will apply a strain of 1000. Accurate results can be obtained from 75 pounds to 75 tons. The machine is in equipoise before the specimen is in place, and is so nicely adjusted, that when a strain of 50 or 75 tons is being made, a half-ounce weight will instantly turn the beam and break the specimen if the necessary strain has been reached. The machine now on exhibition is capable of almost indefinite extension, and will be made 90 feet long. It is intended for E. B. Wood, Esq., of Detroit, Michigan. About twenty machines have thus far been manufactured (one for the United States government), and they have been sent to Cleveland, Cincinnati, Canada, and other places.

An Improved Tool for Turning Metals.—Before a recent meeting of the Institution of Mechanical Engineers, at Birmingham, Col. Clay, of Liverpool, read a paper "On an Improved Construction of Tool for Turning Metals at increased Speed."

This tool has one or more holes drilled through it up to its cutting edge, through which a jet of water is delivered underneath the shaving that is being cut, and upon the cutting edge of the tool, for keeping

it cool in working. By this device the tool is much more effectually cooled than by the ordinary plan of a drop of water falling upon the upper surface of the shaving, in which case little or no water reaches the point of the tool itself. The result of cooling the tool by delivering the water jet direct upon the cutting edge, is that the surface speed of the tool can be increased as much as four times in heavy cuts, and light cuts can be taken at as much as eight times the speed that is practicable with ordinary tools, without any risk of the temper of the cutting edge being destroyed by over-heating. It was stated that the plan had been tried in practice with perfect success.

New Steamship for Laying Cables.—A project which, if consummated, may effect an important decrease in the expense of laying submarine telegraphic lines, is said to be in prospect; a cable manufacturing company of England having the design of building a steamship expressly fitted for their work. This vessel, it is proposed, shall be smaller than the Great Eastern, and much less expensive to run, and shall be capable of carrying 3000 to 4000 miles of cable.

The Niagara Suspension Bridge.—A doubt having arisen as to the safety of the Niagara Suspension Bridge, the directors of the Great Western Railway ordered an investigation to be made. The caps on the towers covering the cables have been removed, and the cables found to be as perfect in all respects as ever they were. But, most important of all, the anchorage of the cables was thoroughly inspected. The masonry over one of them was removed for about twelve feet, or below where the wire is attached to the anchor chains. A portion of the cable is imbedded in water lime cement. For twenty years this has been there, yet, on removing it and rubbing the paint off the wires, the latter were found as bright and perfect as when placed there, the cement having preserved the wire and anchor chains intact. The examination was made in the presence of competent engineers, who have expressed themselves as above to the directors of the bridge company.

Canadian Wooden Railways.*—The wooden railroads built in the vicinity of Quebec have deservedly attracted much attention. The following data regarding them was given to us by Mr. Hurlburt, the projector and contractor of several of these roads. There are now over a hundred miles in operation. The gauge is 4 ft. 8½ inches.

* Railroad Gazette.

The running time is about 16 miles per hour, but trains have been run at the rate of 35 miles per hour. The rails are made of maple, 4x7 inches, set up edgewise, and notched into the cross-ties 4 inches deep, and held by two wedges down in the notch on the outside of the rail. The ties are 8 inches thick, and laid 20 inches apart. The cars have four wheels, and some of the engines weigh 30 tons. In frosty weather the driving wheels have less adhesion than on metal rails, but no considerable difficulty is experienced from this cause. The rails will last from two to four years, according to the quality of the timber and the amount of traffic. The cost of such roads is from four to seven thousand dollars per mile. They seem to be very well adapted for light traffic, and as soon as the business of such lines may require it, metal rails may be substituted for wood without any change in the equipment.

The Union Passenger Depot at St. Louis.—Alluding to the magnificent bridge across the Mississippi at St. Louis, a local paper gives the information that contracts have already been effected with the several railroad companies which secure to the bridge company an average tariff of 65 cents per ton; this item of freight alone yielding a yearly revenue of upwards of $500,000. From other sources it is estimated that not less than $300,000 will be received; thus affording the bridge company a yearly revenue of $800,000, or 8 per cent. on a capital of $10,000,000.

Simultaneously with the completion of the bridge will arise the necessity for a Union passenger depot at St. Louis, to accommodate the several roads leading into that city. The plans for this structure, which is prospected upon a scale of unusual magnificence, we are told have already been approved, and its erection will be inaugurated at no distant day. The part allotted to the railroads is designed to be as complete as possible. It is proposed to employ smoke-consuming engines for the purpose of running the trains into and out of the tunnel and depot. The floors will be deadened, and the trains will be operated by signals.

Marine Photometry.—A correspondent of the New York *Herald*, accompanying Professor Agassiz's expedition on the coast survey steamer *Hassler*, gives a brief but interesting account of an apparatus for determining the relative transparency of the sea at different places, which has already been employed by the expedition at Barbadoes and about the Galapagos Islands. A strip of board, about four inches

wide and four feet long, divided into a scale of ten equal intervals, is painted a dark lead color at one end, fading into white at the other. A large white board having been fastened parallel to it, and at a measured distance below it, the whole arrangement is lowered horizontally into the sea. At the dark end, the upper board appears the darker, but at the white end, the lower board, being seen through a greater depth of water, gives the darker appearance, and, of course, at some intermediate division, the two boards appear to be of the same shade. At that division the relative whiteness of the boards is evidently a measure of the percentage of light absorbed while going down and up again through the distance by which the boards are separated. This relative whiteness is readily estimated at night in the cabin by placing the boards at unequal distances from a candle so as to make them of the same apparent shade at the given division of the scale.

The illuminating powers are to each other as the squares of the distances of the boards from the light. Having once ascertained what percentage of light goes through a fathom, the proportion of daylight which reaches any given depth in the sea can be readily calculated. Suppose, for example, that one-half the light penetrates one fathom; then one quarter goes down two fathoms; one-eighth, three fathoms, and so on indefinitely.

This apparatus is the invention of Dr. Hill, who regards it as still in a crude form and capable of much improvement.

New Method of Cleaning Glassware, etc.—By Dr. I. Walz.—The cleaning of beakers and other chemical glassware that have contained oils, fats and similar organic matters, by means of potassium bichromate and concentrated sulphuric acid, is often inconvenient on account of the shape of the vessels, or because sometimes requiring the application of considerable heat, and thus causing breakage. The following method has given me uniformly satisfactory results: The vessel to be cleaned is filled, or, if large, rinsed with a moderately dilute solution of potassium permanganate, the contact of the liquid being prolonged till a film of hydrated manganic oxide has been deposited; the solution is then poured away, and the glass vessel rinsed with some strong hydrochloric acid. Chlorine is then formed, but not enough to cause inconvenience; and acting *in the nascent state* on the organic matter, it speedily converts them into substitution products, that are soluble in the slight excess of acid or water.

The water of the above also communicates the following description of a *a curious experiment with mercurous nitrate.* A few drops of strong mother solution from the crystallization of mercurous nitrate (proto-nitrate of mercury) are placed into a porcelain capsule; a little mercury is added and divided by means of a glass rod into a number of minute globules. The solution soon begins "to set" around the globules of mercury, and the latter are forced to the top by a kind of capillary action. If the right proportions have been chosen, and this is very easy to do, tubular vermiform formations will begin to grow out of the semi-solid mass in serpentine windings, each bearing a shining little globule of mercury at the end of the tube. Sometimes they grow very rapidly and attain a length of several inches. I have repeatedly prepared this experiment before going home in the evening, and on the morrow found the capsules filled with what appeared like a large number of tiny snakes' heads of silver, in every position of repose or motion.

A Chemical Experiment.—An experiment involving a molecular change in the condition of an element, can be performed as follows:—Let a copper and platinum strip form respectively the negative and positive terminals of a galvanic circuit; immerse these in a hydrochloric solution of chloride of antimony. The result of the galvanic action will be the precipitation of the antimony in form of a fine impalpable powder upon the surface of the copper, from which, when enough has accumulated, it may be readily removed by bending the copper strip back and forth. The metal thus obtained, if placed in a mortar, and vigorously triturated in with the pestle, will detonate with some violence, the explosions being at the same time accompanied with the evolution of light and heat. This curious phenomenon appears to be purely the result of a molecular change, induced in the metal by the mechanical force employed; the consequence being the conversion of the amorphous powder to a crystalline condition. It would be of some interest to note whether the same result would follow the application of heat to the powder, since, from the announcement of Bunsen, made some years ago, the metals rhodium and iridium, when deposited from solutions of their salts in an analogous manner, manifest this property in an extraordinary degree; so much so, indeed, that the scientific world came very near losing the invaluable services of its illustrious discoverer in consequence of a severe accident which befel him from this very unexpected source. It would be

a matter of no little interest to trace the analogy here indicated, to one of positive identity in kind, by investigating the behavior of such precipitated antimony when heated, as was the case with the platinum metals experimented upon by Bunsen.

Friction of Journals and their Proportions.—In its issue of January 11th, 1873, the *Scientific American* has the following article relating to the friction and proportions of journals, which we think worthy of republication in the *Journal of the Franklin Institute:*

"The friction on any surface, whether plane or cylindrical, is proportioned to the weight resting upon it and is not at all affected by the area of the rubbing surface, providing the pressure is not so great, on the one hand, as to change the character of those surfaces, nor so light, on the other hand, as to make the resistance principally that of viscosity of the lubricant rather than that of true friction. In the former case, the friction may increase immensely in consequence of the cutting of the surfaces; and, in the latter, the increase of frictional resistance will be approximately proportional to the increase of area.

"The work done in any given time, that is, the power wasted in turning any journal on its bearings, is, where the frictional resistance is the same, proportional to the speed of the rubbing surfaces, since it is measured by the product of the resistance into the distance through which that resistance is overcome. Therefore, it follows that a very large journal absorbs a larger proportion of the driving power of a machine than does one of small diameter, and in designing machinery we should make journals of as small diameter as possible without danger of breaking the shaft, or of causing abrasion of the rubbing surfaces.

"Again, the tendency of a journal to heat is the greater, the greater the pressure per square inch of longitudinal section of the journal, and it is increased by increasing the speed of the rubbing surfaces. Therefore, to make journals safe against heating, make them of as small diameter as safety permits; and having thus reduced their absorption of power to the lowest limit, secure bearing surface by giving them ample length. If they are, however, made so long that the shaft can spring in the journal, heating may occur from that cause; in line shafting, this will, of course, not happen. The best practice gives line shafting for mills a length of journal equal to four times the diameter of the shaft.

"There are rules, known to engineers, for properly designing journals, which are based on the principles above stated. The earliest of which we have knowledge is that of Professor R. H. Thurston, which was based upon observation of the action of crank shafts of naval steamers in 1862. A somewhat similar rule, based on locomotive practice, was published by Professor W. J. M. Rankine, in 1865. The first is expressed as follows:

$l = \frac{PV}{60000\ d}$; and $\frac{P}{ld} = \frac{60000}{V} = p$. The second is, $\frac{44800}{V \text{ plus } 20} = p$; and, when reduced to the same form as that of Professor Thurston, becomes $l = \frac{P\ (V \text{ plus } 20)}{44800\ d}$.

"Here l = length of journal in inches; P = total pressure on journal; p = pressure per square inch of longitudinal section; V = velocity of rubbing, in feet, per minute; d = diameter of journal in inches.

"In no case in general practice should the pressure, on even the slowest moving journals, be allowed to exceed 1,000 pounds per sq. inch of longitudinal section with steel journals, or about 600 on iron, running in well worn boxes in each case.

"Special care should always be taken to provide for effective lubrication."

Commercial Production of Hydrogen.—M. Tessié du Mothay, whose name is familiar to the readers of the "JOURNAL" as the inventor of a number of processes in manufacturing chemistry—prominent among which are those for producing oxygen and chlorine continuously—has recently published a method of producing hydrogen upon a large scale; the ultimate design of the inventor being the utilization of the gas as an illuminating agent after carburetting with light petroleum oil, or similar substances.

It consists, according to his description, in leading steam into a furnace of coke heated to redness. By this treatment, hydrogen and carbonic oxide are formed. From this mixture the carbonic oxide is removed by passing the gases through a series of cylinders filled with hydrated lime heated to redness. The result of this last process is the formation of a fresh equivalent of hydrogen and the conversion of the carbonic oxide into carbonic acid by union with the oxygen liberated from the water of hydration. The carbonic acid remains behind as lime carbonate, while the hydrogen is passed through or over

one of the light petroleum oils, by which it becomes carburetted, and is in this condition passed through tubes heated to a low red heat, whereby the gas and vapor are converted into a permanent gas—of high illuminating quality—and well adapted for lighting or for heating purposes.

Carbon from Gas.—It is reported, upon reliable authority, that a company has been established, and is now in operation, with the object of manufacturing lampblack from the escaping gas of an abandoned oil-well at or near Cumberland, Md.

The gas-flames are directed against soapstone plates, and upon these the deposit of soot is made, which is subsequently removed by suitable means and packed in tin boxes of convenient size for transportation. At present there are said to be 660 8-foot burners in operation. It is further stated that the company contemplate shortly increasing its operations by the erection of a larger building and the introduction of double the numbers.

This method of utilizing what would be otherwise simply a waste product is worthy of emulation, and is, we believe, a purely original idea with the projector of the enterprise, Mr. Horworth, of Boston.

Newly Discovered Tin Fields.—The importance attaching to the multiplication of the sources of obtaining tin, gives rise every now and then to sensational accounts of wonderful finds of ores of this metal. With some of these reported localities in our own country the readers of the "Journal" will be familiar. At length, however, the world is furnished with the statement that a tin field of unexampled richness has been discovered in the English colony of Queensland, and the statement is substantiated so fully that there can remain no reasonable ground to doubt the fact that the discoveries are both genuine and important. The reports state that the presence of tin has been detected over an area of 550 square miles, the richest source being the river gravels. It seems possible, therefore, that Eastern Australia may soon compete with Cornwall as a tin-producing country.

A New Experiment.—If fifteen to twenty grammes of granulated silver are introduced together with 30 to 40 grammes of bisulphide of carbon into a hard white glass tube, and hermetically sealed, then, upon gently warming and then shaking in the dark, sparks will be observed in the tube, which by continued shaking may be rendered quite luminous. Pouring water on the tube causes the luminosity to disappear, but, upon shaking, it re-appears again.

Bursting of a Fly-Wheel.*—An English contemporary contains an account of a disastrous accident of this kind which recently occurred at the Bolton Iron and Steel Works, which involved a loss of life and immense damage to property. The accident occurred in the rail-mill, where some twenty persons are employed day and night. After the starting of the engine, the belt came off the governor-shaft, which caused the engine to run at a greatly accelerated speed, the consequence being that the fly-wheel, 26 feet in diameter, and weighing 60 tons, flew asunder with a loud report, the fragments of which, eight in number, were projected with destructive effect into the works. The roof of the mill was brought down, the boilers, rolls and machinery of the mill greatly damaged, while other fragments were projected beyond the building with equally destructive results. Nearly all the workmen in the mill at the time were more or less injured.

It is doubtful whether any case of this kind is upon record, which can equal this one in violence.

The "Devastation."—The contest between artillerists and naval architects has culminated in the production of the "Devastation," "Thunderer," and "Fury," protected by 12 inches of armor, and of 35-ton guns to perforate such plates at the distance of 1000 yards. The "Devastation," a ship of 9188 tons displacement, and 5600 indicated horse-power, is the first sea-going ship-of-war designed without sails. Carrying 1600 tons of coal, she is expected to run, at a 5-knot speed, about 9200 miles without replenishing her coal-bunkers. Her side armor of 12 inches is only penetrable to 25-ton guns when struck at right angles, within 200 or 300 yards' range. The 14-inch iron plates on the front of the turrets would be impenetrable to British 25-ton guns as at present rifled. The total weight of armor carried by the "Devastation" is twice as great as that which protects the turret-ship "Monarch," of 8322 tons, and is equal to more than three-quarters of the weight of the hull which carries it. This is the most advanced of the three mastless ships, each of which is intended to carry four 35-ton guns in two turrets, throwing at each discharge 2800 lbs. of iron with a striking force at their muzzles of 31,412 foot-tons. Enormous as is this offensive power, it hardly bears a due proportion to the defensive superiority of the "Devastation" over other sea-going ships. True, each gun would perforate armor which would be impenetrable to those of any other ships, but such as is not yet carried by

* Engineer, xxxv, 18.

foreign vessels. There are very few foreign iron-clads whose sides would not be equally penetrable to 18 and 25-ton guns, whilst the shell power of such guns is greatly superior to that of the 35-ton gun. In bombarding fortresses the sums of the squares of the bursting charges of the shells may be taken as the measure of offensive power. The "Devastation" could at each discharge explode only 80½ lbs. of powder within a fortress, but the "Monarch" would explode more than double that quantity, and the "Sultan," using only one broadside, would explode 60 lbs. more than the "Devastation." Adding together the squares of their bursters, the relative shell power of these ships on one broadside is—"Devastation," 1620; "Monarch," 5386; and "Sultan," 3404.—COMMANDER W. DAWSON, *in "Naval Science" for October.*

AMERICAN SOCIETY OF CIVIL ENGINEERS.

The following abstract of the proceedings of the Society came too late for insertion in its appropriate department:

A regular meeting of this Society was held at its rooms, in New York, January 8th.

A paper, by Charles B. Richards, M. E., of Hartford, Conn., recording "Experiments on the Resistance of Stones to Crushing," was read.

The specimens tested were old and dry samples, well selected, of various American building stones, worked into 1″ and 1½″ cubes, with flat and smooth faces.

The testing machine used was built after a long experience with two smaller and similar machines. It is arranged to weigh the strains upon a sensitive platform scale of 50 tons capacity, and is well adapted to quickly give accurate results.

The specimens were crushed between the plane faces of two hardened steel hemispheres, the curved portions of which were seated in corresponding cavities of steel blocks, fixed in the machine. Single thicknesses of "lace" leather were interposed between the stones and metal surfaces; thus the pressure was uniformly distributed; it was, in all cases, applied to the faces of the cubes, parallel to the natural bed of the stone, and carefully increased to rupture by pouring shot into the hollow weight by which the strain was caused.

Tables were presented, giving the minimum, mean, and maximum resistance to crushing per square inch of the specimens tested.

Sixteen specimens of granite, from six quarries, gave from 8620 to 15,622 pounds minimum, 9838 to 18,778 pounds maximum strength;* and ten specimens of *white marble*, from three quarries, gave from 3905 to 12,917 minimum, and 5976 and 13,972 pounds maximum strength—each being 1″ cubes.

The specimens failed by breaking up into slender prisms and pyramids, with axes normal to the pressure.

A brief paper, by F. Collingwood, C. E., of New York, upon "Rock Drilling," was also read.

In it was stated that a percussive steam-drill, with 3″ cylinder and 6″ stroke, making 300 to 375 strokes per minute, would drill in the coarse gneiss rock, common on New York Island, $1\frac{5}{8}$″ holes 3″, $1\frac{3}{8}$″ holes $4\frac{1}{2}$″ and 1″ holes 5″ per minute.

Joseph P. Davis, C. E., of Boston, Mass., compared the late Chicago and Boston fires, and suggested a question for discussion, and one on which information is much needed, namely, "Fires and their Management; the Best Appliances and Methods for Putting them Out."

Upon motion of M. N. Forney, M. E., of New York, a committee, consisting of Messrs. Asabell Welch of Lambertville, N. J., John Griffin of Phœnixville, Pa., Max Hjortzberg of Chicago, Ill., and two others to be named by the Chairman, were appointed to make an investigation, by means of a circular of inquiry sent to each member of the Society, and by such other methods as the committee may choose to adopt, to determine the following points:

1. The best form for standard rail sections for the railroads of this country.

2. The proportion which the weight of rails should bear to the maximum loads carried on a single pair of wheels of locomotives or cars.

3. The best method of manufacturing and testing rails.

4. The endurance or, as it is called, the "life" of rails.

5. The causes of the breaking of rails while in use, and the most effective way of preventing it.

The Committee to report the results of their investigations at the next annual convention of the Society.

* Fourteen specimens of sandstone, from three quarries, gave from 5806 pounds minimum, and 8956 to 10923 pounds maximum strength.

Civil and Mechanical Engineering.

INTEROCEANIC COMMUNICATION.

By Prof. J. E. Nourse, U.S.N.

(Continued from Vol. LXIII, page 313.)

* The Nicaragua Route.

On apparently very strong grounds, this line for a ship canal has, at different times, enlisted the attention of many who were not mere adventurers or money-schemers. This last term is applied to all such parties as have exerted themselves sufficiently to revive an old idea on some one of these lines, in order chiefly to the organization of companies, so-called, or the sale of enough of stock to pay salaries and working expenses in breaking ground only, and then to the sale or forfeiture of an obtained concession. It is not to be disguised that, unfortunately for the interests of a true survey, there is such a record. And it cannot be too much insisted upon by those who look for final success, that such a survey will never be secured except under an organized party, who have ability enough to know and appreciate the whole work before them, having in their service persons of experience in dealing with the great difficulties in these tropical jungles, marshes and mountains.

More than one reported success, but true *failure*, can be traced back to a serious lack here.

The strongest claims for a final survey of the Nicaragua route for a transit suited to the wants of the age, are the water communication of the central lakes and their ability to feed the remaining line of the canal.

By the water communications hopefully to be established through the lakes and their outlets, the isthmus "may be reduced to about one-tenth of its whole breadth."

In the bodies of water within these lakes a reservoir or feeder exists such as is found on no other of the lines; their narrowness permits no such water supply. Secure, then, any new or improved harbor facilities, and a canalization of the outlets on this line, and the canal seems surely practicable.

Let us look at a few chapters in its history.

* This article, in a series nearly completed, has been designedly delayed until the facts furnished by the recent Government Expedition, and those in connection with a second, now preparing, could be available.

First Attempts by Great Britain.

Great Britain has made several unfortunate efforts to possess herself of the route for an inter-oceanic canal through Nicaragua. The first was in 1740, by the Superintendent of the Moschito Coast; this was disavowed by the Government.

Somewhat later a more noted effort was made. In 1780, Captain, afterward Lord Nelson, under orders from Admiral Sir Peter Parker, convoyed a force of 2000 men, under Col. Polson, with original instructions limiting his own responsibility to the convoy only. But Nelson (then at the age only of 22) found it necessary to take a more active part. His plan of operations reads thus: "In order to give facility to the *great object* of Government, I intend to possess the Lake of Nicaragua, which for the present may be looked upon as the inland Gibraltar of Spanish America. As it commands the only water pass between the oceans, its situation must ever render it a principal post to insure passage to the Southern Ocean, and by our possession of it Spanish America is severed into two."

The expedition reached San Juan March 24th, 1780, "in good health and spirits." Of the squadron, composed of two frigates, two brigs-of-war and a line-of-battle-ship, none would venture to cross the bar except Nelson's corvette. It was the end of the dry season. The passage of the San Juan was exceedingly difficult; for the seamen, although assisted by Indians from Blewtown, scarcely forced their loaded boats up the shoals, and their exposure to the sand-heats and night dews, without sufficient provisions,* or the possibility of hospital care, made fearful havoc with their health. Nelson leaped ashore with a few seamen, stormed the first Spanish battery, 16 miles below San Carlos, and took that fort itself on the 24th of the month. But although the capture was made (Nelson here "commencing his career of glory"), he himself and the few officers and men who survived barely escaped with their lives. "So general was the sickness that enough orderly men were not left to attend the sick." Out of eighteen hundred men scarce three hundred ever left Nicaragua. Of a crew of two hundred men, on the Hinchinbrook, eighty-seven took to their beds in one night. * * * The remnant returned to Jamaica in October. "Had the expedition," said Nelson, "arrived at San

* "At one time they were obliged to subsist chiefly on broth made by boiling the monkeys that were caught. Nelson never could touch this, after once seeing the monkeys in the cauldron."

Juan's harbor in January, the violent torrents would have subsided, and the whole force would not have had to get wet, while dragging their boats, three or four times each day."

Movements in Nicaragua in this Century.

After the establishment of independence in Central America, the first attempt towards opening the canal was made by Senor de la Cerda, afterwards Governor, who urged it upon the Federal Congress in the year 1823; but the succeeding disturbances deferred all movements until 1825, when the Congress passed a decree authorizing its opening. Proposals were made by Mr. Bayley, agent for Barclay & Co., and by Mr. Beniski, for Aaron Palmer & Co., of New York. The Nicaraguan Government, though aware of Mr. Bayley's character and experience, preferred to take an unconditional offer from Beniski, who promised to pay down $200,000, and open a canal. A scheme was announced as under the patronage of the President of the United States, and of eminent New York men, including De Witt Clinton. No capital was raised.

In 1828, the King of the Netherlands proposed to undertake the work, if a survey should show its practicability. The Dutch General Verveer came over with instructions to undertake the canal. He found Central America in the midst of one of her incessant revolutions; the matter was deferred; the liberal offers of the Dutch Government were not finally closed, and the revolutions in their own country (1830) put an end to the plans.

March 3d, 1835, a resolution passed the U. S. Senate that the President be requested to consider the expediency of opening negotiations with other governments, and particularly with Central America, for protecting individuals or companies who may undertake to open a communication between the Atlantic and Pacific Oceans. A special agent was appointed by Gen. Jackson—Mr. Charles Biddle, formerly of Philadelphia—to visit the different routes best adapted for interoceanic transit. He appears, however, to have visited only the line of the present Panama Railroad, and, after this visit and an attendance on the Congress at Bogota, where he received information on the different lines, he returned to the United States, regarding his success in the examination of the Panama line for the purpose of a railroad sufficient to warrant him in omitting further investigations. His instructions had been to proceed to San Juan and the Nicaragua Lake; but, from the difficulty of obtaining a conveyance to San Juan,

he had landed at Panama. Mr. Biddle died before reaching Washington to report upon his mission.

Bailey's Surveys.

In 1837, Gen. Morazan, President of Nicaragua, resolved to have accurate surveys made, intending to raise a loan in Europe. Mr. John Bailey, Lieut. of Marines, H. P., for 20 years resident in Nicaragua, was employed for this purpose. His results were communicated to the Royal Geographical Society in 1844, but only partially published.

It appears that in 1837–38, he "surveyed the Lake of Grenada (Nicaragua), the River San Juan, flowing out of it at the port of San Juan del Norte, lat. 10° 56′ 45″ N., long. 83° 43′ 14″ W., and the isthmus between the lake and San Juan del Sur, lat. 11° 15′ 37″ N., long. 85° 52′ 56″ W."

His proposed line, as given in the Society's Journal, and afterwards in his own work, published in 1850, was the course of the San Juan del Norte, thence by the Lake Nicaragua, terminating in the coast at San Juan del Sur. Between that port and the mouth of the Lajas River, emptying into Lake Nicaragua, a line of levels—"a series of 351 levels"—was taken in 1838, at different stations.

	Feet.
From these levels he made the sum of the ascents, . .	1047
The sum of the descents, ...	919
Hence the difference or height of Lake Nicaragua above the Pacific Ocean, at low water, is	128

This result has a near approximation to that quoted by Thompson in his "Guatemala," as obtained from a series of 347 water levels, at an average distance of 100 yards each, made by order of the Captain General Galvez, the excess of descents then ascertained being 133 feet.

It was considered unfortunate by some that Bailey's survey was not carried on the line passing through the Lakes Managua to the port Realejo. On the other hand, Capt. Belcher, R. N., in 1837, found it necessary to correct the accounts which represented Realejo as a harbor. He says: "Trusting to the accounts I had read of the magnificence of this port, I had fully intended placing the 'Sulphur' (380 tons) near the town. The visit of the captain of the port soon undeceived me. He assured me that, at low water, not more than three

feet would be found near the town, and so narrow that there was barely room for the oars of my gig. * * The distance from the position where vessels usually anchor (Cardon) to Realejo is a sad drawback." Cardon, *nine miles* from Realejo, has two entrances, both of which are safe under proper precaution.

Mr. Bailey doubtless did an arduous and faithful work for more than two years on this survey. By the dissolution of the Federal Government, and the repudiation of its debts by each State, he seems to have utterly failed of reward.

The surveys by Bailey had revived the plans of Galisteo (1781), and popularized in Nicaragua the idea of a canal. From 1838, therefore, to 1846, movements for it were set on foot with Belgium, and with Louis Napoleon while a prisoner in the fortress of Ham. M. Castellon (afterward slain during Walker's invasion) was sent in 1844, by Guatemala, San Salvador and Honduras, to solicit the protection of France, and in return to offer the commercial advantages of the country. M. Guizot was at that time already committed to a full examination of the *Panama* route, given into Garella's charge during the previous year,—a route, too, where no conflict with British interests was involved. Castellon, however, received permission to visit Louis Napoleon. He succeeded in impressing him with the idea of the work in Nicaragua with sufficient favor to obtain from the Prince the decision that, if he should recover his liberty, he would proceed to America and undertake the canal. A decree in 1846 assigned to the enterprise the name "Canale Napoleone de Nicaragua." But the captive was not allowed to go over; the destinies of France were to be in his hands; the influence he had always coveted to wield for the Latin race and for France in the western world was never to be wielded. After Napoleon's arrival in London, he earnestly advocated before the Institution of Civil Engineers the superior advantages of this route. In a pamphlet, with the initials L. N. B., and more fully in "Les Œuvres de Napoleon," Vol. II, a route terminating on the Pacific at Realejo, and the plans of development for Central America, were drawn out. In order to secure this end, he advocates a line not to cut through the narrowest tongue of land, but through the country most populous, fertile, healthy, and crossed by the greatest number of rivers. "There are some countries," says the Prince, "which, by their geographical position, are destined to the highest rank in prosperity, provided that, where nature has done everything for man, he does not neglect to make use of the advantage placed in his hands.

Tyre, Carthage, Constantinople, Venice, London; and, in the new world, Leon or Massaya—as favorably situated as Constantinople in the old—are noted examples of what prosperity may be attained by places situated like these for commerce."

M. Felix Belly himself, afterward so closely connected with the Nicaraguan plans, says of the Prince's ideas, at this time, that they were a reviving of the old dreams of attaining the wealth of the East. "The Eastern vision of Constantinople and the Indies had been destroyed by the guns of Sydney Smith at St. Jean d'Acre; this new Western vision before Napoleon borrowed intensity every day from the ennui of a five years' confinement." The vision, however, early sank out of view in the West. The pamphlet, "L. N. B.," and the detailed route, estimated cost and revenues of the "Canale Napoleone" in his works, are all which remain.

Political and commercial events came on of higher moment than the attempted transfer even of a Napoleon to our hemisphere. The gold fields of California, in 1849, opened up the great change. Their discovery, by creating necessities for the transportation of the multitudes whom they seemed to invite, stirred again direct propositions to the Government of Nicaragua. Mr. Wheelwright, the projector of a British line of steamers on the west coast of South America, with some American citizens alive to the enterprise, asked a concession. In the meantime England, reviving the ideas of Nelson's day, bent its whole policy in Central America to acquiring permanent control of the isthmus. In January, 1848, she siezed the port of San Juan, naming it—in honor of Lord Grey, then Governor of Jamaica, and as the terminus of a canal—*Greytown*. The British Vice-Consul Manning wrote Lord Palmerston, earnestly urging a British Protectorate, in order to "obtain control of so desirable a spot in the commercial world, and to free it from the competition of so adventurous a race as the North Americans."

As the final result of representations against these English movements, made in 1847—48 to the President of the United States by the Supreme Director and by the Secretary of State of Nicaragua, Mr. Hise, and afterward Mr. E. G. Squier, were sent on missions chiefly in regard to the transit. Messrs. Vanderbilt and White, being at the same time applicants before the Government of Nicaragua for a canal charter, succeeded in obtaining a liberal concession for the "American Atlantic and Pacific Ship Canal Company," the American Chargé having given to the grantors assurance that his govern-

ment would extend its guarantees to a proper charter. The treaty stipulations made in connection with this grant were ratified unanimously by Nicaragua, but gave way in the United States to the famous Clayton-Bulwer Treaty, which was believed by the American Secretary of State to secure unequivocally "the liberation of Central America from the dominion of any foreign power."

The Company organized in New York for the construction of a canal, sent out Col. O. W. Childs, a distinguished engineer of Philadelphia, to make a full survey. As exhibiting the entire confidence held by the projectors in the enterprise, a public banquet was given by them February 12th, 1850, before even a reconnoissance had been made. In January, 1851, the successful passage of the San Juan and navigation by a steamer on the Lake Nicaragua, was hailed with enthusiasm. The movement itself, in connection with the increase of adventurers to California, largely influenced emigration and purchase in Nicaragua, lands advancing in price in the projected town of "Corinth," on the Bay of Realejo, from four francs to one hundred and twenty-five per hectare.

But although a wondrous activity in trade was temporarily aroused in Nicaragua, and there seemed every promise one could desire for that country as a token of what true benefits would accrue if the canal were opened, three things forcibly arrested its best prospects. These were the disfavor shown by capitalists in England to the report of Col. Childs; the fact that greater gains by far were to be realized by using this route as a mere passenger transit than by going on with a canal project; and, lastly, the miserable invasion of the country by Walker's Buccaneers. The report of Col. Childs estimated for a canal of but 17 feet in depth and 50 feet in width (nearly 10 feet less in depth and nearly 200 feet less in width than the Suez Ship Canal), at a cost of $31,500,000. The report, as well as the survey itself, was a work of the highest character, trustworthy and safe. But the English capitalists shrank from an investment in an enterprise the report of which, though conforming to the requirements of modern engineering, admitted that an increase in cost would by no means be proportionated to the increased dimensions required for the commerce of the age. The original charter to the American Atlantic and Pacific Ship Canal Company, was permitted by the Nicaragua Government to have its ship canal powers and privileges *reserved* and separated, and a new company, "The Accessory Transit Company," was formed under its franchise. The profits of travel and traffic under

this minor arrangement, carried the larger original enterprise out of view; and the invasion and misrule of Walker closed off public attention.

The conflict between the Company and the buccaneer brought on the destruction of Greytown, and left an evil feeling against Americans in place of the advanced good feeling which had prevailed. It seriously injured the transit of passengers. Yet, between 1851 and 1867—a date later than belongs to the thread of our narrative at this point—the large number of 150,000 passengers were conveyed across this route. It was an opposition line to the Panama Railroad.

Two eras in the history of the route remain to be noticed:

I. The first is the outlay by the "Central American Transit Company" in their projected improvement of the harbor of Greytown. In 1865, Capt. Preston C. F. West, of U. S. Coast Survey, was appointed to make surveys which would "determine the practicability of improving the San Juan River, and of reclaiming the harbor of Greytown. His appointment was the result of an application from Don L. Molina, Minister from Nicaragua to the United States, and in conformity with an article in the contract between the Nicaraguan Government and the Company. Capt. West's report was unwillingly but decidedly unfavorable. In respect of Greytown, especially, he reported: "After carefully studying the question of improvement to admit ocean steamships, I am sorry to be obliged to recommend the abandonment of the idea." The whole report was, however, submitted by the disappointed parties to a Commission asked for by the Secretary of State (on the application of the Nicaraguan Minister) from the National Academy of Sciences. This Board, consisting of General Humphreys, U. S. A., Admiral Davis, U. S. N., and Messrs. Hilgard and Mitchell, of the Coast Survey, confirmed in the main the judgments expressed by Capt. West. The outlay by the Company of a large amount in spite of these unfavorable auspices, was almost an unmodified loss.

II. The consolidation of the interests of the original Atlantic and Pacific Steamship Canal Company, the Accessory Transit Company and the Central American Transit Company into the one Company last named, awakens a new financial and commercial interest in the route, and has led to an expedition for further surveys authorized by the Navy Department, under an Act of Congress of 1871.

An expedition, under command of A. F. Crosman, U. S. N., of Philadelphia, left the United States in the Spring of 1872. The

season was too far advanced toward the beginning of the tropical rains to permit more than a mere reconnoissance for a proper survey in the Fall. Com. Crosman's instructions contemplated an examination of Limon Bay on the south and Monkey point on the north, as a substitute, if possible in either case, for the lost harbor of Greytown; also, the running of a line of levels on some new and more promising route from Lake Nicaragua to the Pacific.

Having but just landed a party of observation at Port Limon, and arranged for landing and beginning full work by ascending the Colorado river, most unhappily the commander was drowned, together with Master Foree, U. S. N., and four men, off the bar at Greytown, April 7th, 1872.

Com. Hatfield, U. S. N., assuming the charge of the expedition, ascended the Colorado, and, from its junction, the San Juan also, to Fort San Carlos, experiencing the same difficulties in kind in getting his steam launch up the rapids, as Nelson in his day found with his boats. In nine days, however, he placed the launch on the great lake, provided for its employ in taking the soundings necessary upon it, and, proceeding to La Virgin, organized parties for surveys from the mouths of the Sapoa and the Lajas. The line from the lake to Salinas Bay by the river Sapoa proved entirely impracticable, by reason of the altitude of the summit level. One of Col. Child's original lines was examined with more favorable results than offered by him. A new line, including part of this and measuring, it is believed, but sixteen miles from the Lake, was begun. It will be the first resumed by the party organizing at the date of this communication, under Commander E. P. Lull, U. S. N., who was selected by the Navy Department to pursue these investigations immediately on the report of Commander Crossman's death. Another line was begun by Commander Hatfield, by the River Ochomaga; sufficient time, however—only five weeks of work in all—could not be given by Hatfield's expedition to secure any full basis of decision on the routes. His faithful labors were commended by the Government.

There is this encouraging fact to those who have hope of the Nicaragua route, as probably the last hope of securing early a ship canal on this Continent, that both Col. Childs and several of his assistants in the survey of 1851–52, including Mr. Sweet and Mr. Cropsey, of the New York Engineers, have confidently believed that a practicable route can and will here be found.

The Navy Department now sends there an able and experienced of-

ficer, previously on the isthmus explorations; he will accomplish what can be done in securing that which the now assured success of the Suez Canal more than ever demands for American commerce and our American name.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from Vol. LXIV, page 344.)

Frictional Gearing.—"Frictional Gearing is a term applied by Webster to wheels that transmit motion by surface contact without teeth. This style of gearing is much used in the lumbering region of the 'north west,' and is fast gaining favor wherever applied. It has some advantages, not possessed by other modes of communicating motion, which do not appear to be counteracted by any peculiar disadvantages.

"In large mills where this gearing is used to transmit power to drive five or six gangs, one or two large circular saws, a muley, gang edgers, trimmers, slashers, lath mills, shingle mills and other machinery, where 20,000 feet of boards may be sawn in an hour, the faces of the wheels are made as smooth and straight as possible; one wheel is made of iron and the other of wood, or of iron covered with wood.

"Where it is practicable, this gearing is so arranged that the wood drives the iron, to prevent the 'slip' at starting from wearing the wood-faced wheel unevenly. Although this tendency is much less than might be supposed, as in most cases the 'bull-wheel,' used for drawing logs into the mill, is a large wooden wheel driven by a small one of iron, and these wheels, started and stopped while the driver is in full motion a hundred times a day, work well and last for several years. But for machinery in constant use, the wooden wheel should always drive the iron wheel.

"For driving heavy machinery, the wooden drivers are put upon the engine shaft, and each machine is driven by a separate counter-shaft. Two or more of these counter-shafts are usually driven by contact with the same wheel, and each is arranged so as to be thrown out from the driver and stopped whenever required, and again started at any moment, by a slight movement, without interference with other machinery.

"To drive small machinery, these friction drivers are put upon a line shaft so as to drive a small counter-shaft, from which the machine is driven by a belt, which may be shifted in the usual way.

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"In many mills from 100 to 300 horse power are transmitted by this kind of gearing.

"For driving light machinery, running at high speed, as in sash, door and blind factories, basswood—the linden of the Southern and Middle States—has been found to possess good qualities, having considerable durability and being unsurpassed in the smoothness and softness of its movement. Cotton-wood has been tried for small machinery, with results somewhat similar to those of basswood, but is found to be more affected by atmospheric changes; even white pine makes a driving surface which is, considering the softness of the wood, of astonishing efficiency and durability. But for all heavy work, where from 20 to 60 horse power is transmitted by a single contact, soft maple has, at present, no rival. Driving pulleys of this wood, if correctly proportioned and well built, will run for years with no perceptible wear. For very small pulleys, leather is an excellent driver, and very durable.

"Recently paper has been introduced as a driver for small machinery, and has been applied in some situations where the test was most severe; and the remarkable manner in which it has thus far withstood the severity of these tests, appears to point to it as the most efficient material yet tried.

"The proportioning of friction pulleys to the work required, and their substantial and accurate construction, are matters of perhaps more importance than the selection of material. The mechanic who thinks he can put up frictional gearing temporarily and cheaply will make it a failure. Leather belts may be made to submit to all manner of abuse, but it is not so with friction pulleys. They must be accurately and substantially made, and put up and kept in perfect line.

"All large drivers, say from 4 to 10 feet diameter, and from 12 to 30 inch face, should have rims of soft maple 6 or 7 inches deep. These should be made up of plank, 1½ or 2 inches thick, cut into 'cants,' $\frac{1}{6}$, $\frac{1}{8}$, or $\frac{1}{10}$ of a circle, so as to place the grain of the wood as nearly as practicable in the direction of the circumference. The cants should be closely fitted, and be put together with white lead or glue, strongly nailed and bolted. The wooden rim thus made up to within about 3 inches of the width required for the finished pulley, is mounted upon one or two heavy iron 'spiders,' with 6 or 8 radial arms. If the pulley is above 6 feet in diameter, there should be 8 arms, and 2 spiders when the width of face is more than 18 inches.

"Upon the ends of the arms are flat 'pads,' which should be of

U of M

just sufficient width to extend across the inner face of the wooden rim, as described, that is, 3 inches less than the width of the finished pulley. These pads are gained into the inner side of the rim, the gains being cut large enough to admit keys under and beside the pads. When the keys are well driven, strong 'lag' screws are put through the ends of the arm into the rim. This done, an additional 'round' is put upon each side of the rim to cover bolt heads and secure the keys from ever working out. The pulley is now put to its place on the shaft and keyed, the edges trued up, and the face turned off with the utmost exactness.

"For small drivers, the best construction is to make an iron pulley of about 8 inches less diameter and 3 inches less face than the pulley required. Have 4 lugs about one inch square cast across the face of this pulley. Make a wooden rim, 4 inches deep, with face equal to that of the iron pulley, and the inside diameter equal to the outer diameter of the iron. Drive this rim snugly on over the rim of the iron pulley, having cut gains to receive the lugs, together with a hard wood key beside each. Now add a round of cants upon each side, with their diameter less than the first, so as to cover the iron rim. If the pulley is designed for heavy work, the wood should be maple, and should be well fastened by lag screws put through the iron rim. But for light work, it may be of basswood or pine, and the lag screws omitted. But in all cases the wood should be thoroughly seasoned.

"In the early use of friction gearing, when it was used only as backing gear in saw-mills, and for hoisting in grist-mills, the pulleys were made so as to present the end of the wood to the surface; and we occasionally yet meet with an instance where they are so made. But such pulleys never run so smoothly nor drive so well as those made with the fibre more nearly in line with the work. Besides, it is much more difficult to make up a pulley with the grain placed radially, and to secure it so that the blocks will not split when put to heavy work, than it is to make it up as above described.

"As to the width of face required in frictional gearing, when the drivers are of maple, a width of face equal to that required for a good single leather belt to do the same work, is sufficient. Or, to speak more definitely, when the travel of the surface is equal to 1200 feet per minute, the width of face should be at least one inch for each horse-power to be transmitted, and for drivers of bass wood or pine, 1½ to 2 inches.

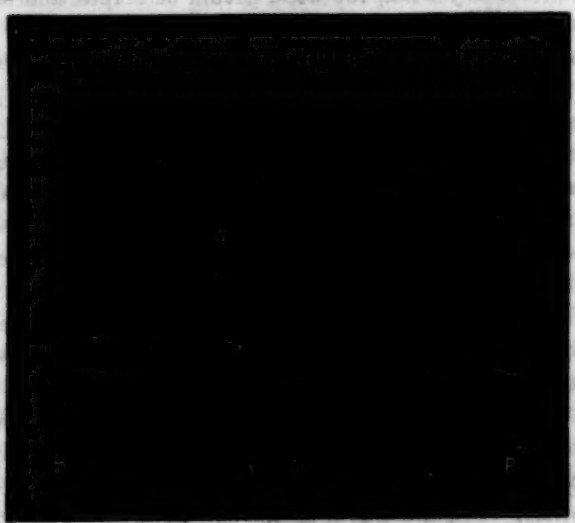
"The driven pulleys are wholly of iron, and similar to belt pulleys,

but much heavier, having more arms and stronger rim. The arms should be straight rather than curved, and there should be two sets of arms when the face of the pulley is above 16 inches. A very good rule is to make the thickness of the rim 2½ per cent. of the diameter of the pulley.

"To secure perfect accuracy, these pulleys must be fitted and turned upon the shaft; and when large, the shaft should run in journal boxes, while the face is being turned, after which they should be balanced, neglect of which has been the means of destroying friction pulleys that otherwise were well made."

"The conditions and results of a few experiments, made to test the tractive power of smooth faced friction pulleys, are here given. These experiments, when made, were not meant for publication or for the benefit of science, but to establish rules for private practice. They should be repeated by others before being taken as conclusive.

"For the experiments, two pulleys were made in the usual way, one being of wood—soft maple—and the other of iron. Both were accurately and smoothly finished. These pulleys were each 17 inches in diameter, and of 6 inch face, and were put up as shown in the annexed diagram:



"A is a double bell crank frame, with arms 2 feet long. The ends of the upright arms receive the bearings for the iron pulley, I. The journals of this pulley are 1½ inches diameter and 3 inches long, and run in Babbitt boxes. The frame is hung upon journals, T, and is

balanced by the weight, B. The face of the pulley, I, is extended beyond the six inches to receive the cord, C, for which purpose a shallow groove is cut in the pulley, so as to bring the centre of the cord to the periphery. The driving pulley, V, is put upon a shaft where it may be made to revolve slowly in the direction of the arrow.

"It will be seen that P will bring the pulleys together with a pressure just equal to its weight. The wooden pulley being in motion, the pressure, when sufficient, will roll the other pulley and raise the weight, W.

"The manner of experimenting was to put a given weight upon the cord, C, and while the driving pulley was moving, to increase the weight, P, until W was lifted. The machinery was then stopped, when the weight would descend, slipping the iron pulley upon the wood. The weight of P was now noted; the weight was again raised, and the pressure increased sufficiently to hold the weight from slipping down, and the pressure again noted.

"After these experiments were made and twice repeated with the pulleys, the frame, A, was reversed, so that the weight, P, would tend to separate the pulleys. They were then connected by a 6-inch leather belt, and the experiments repeated, giving the results in the fourth and fifth columns.

	Friction Pulleys.		Belted Pulleys.	
Weight raised.	Pressure required to just raise the weight.	Pressure required to raise the weight without slip.	Pressure required to raise the weight.	Pressure required to raise the weight without slip.
10	29	53	30	34
20	58	65	60	69
30	87	96	91	120
40	115.	125	121	159
50	143	154	153	199
60	171	185	183	242
70	199	214	213	247
80	225	244	239	332
90	264	289	278	375
100	295	312	310	419
120	354	387	372	487
140	416	438	442	563
160	477	499	524	652
180	538	561	592	731

"It will be seen that, in this test, the traction of the friction wheels was greater than that of the belted pulleys, and considerably more than is usually supposed to be obtained from belts upon pulleys of either wood or iron; and that while there is a marked falling off in the adhesion of the belt as the work increased, that of the friction increases as the labor becomes greater. Also that the difference in the pressure required to just do the work, and that necessary to do it without loss or slip, advances in an increasing ratio with the work of the belt; but in the friction it is almost constant throughout the whole range of experiments. The figures applied to the friction wheels are the mean results of repeated experiments; those applied to the belted pulleys are each of a single test. It is not thought that these experiments were sufficient to fully establish all that the figures show; but they were enough to prove that smooth faced wheels possess a much higher tractive power than has been generally supposed.

"And now a word as to some of the advantages of friction gearing. Being always arranged with a movable shaft, so that the wheels may be thrown together or apart with the greatest ease, the machine driven by it is started and stopped at any moment, while the driving wheel remains in motion. And when stopped, the separation is complete, and may so remain for any number of minutes or months without attention, and may be again started at any moment without the least inconvenience or injury. So slight is the separation required, that it is done almost without an effort. And by it we entirely dispense with the nuisance of loose pulleys, belt shifters and idle running belts, and with the risk of throwing off and putting on belts. It obviates the delay and labor of shipping and unshipping pinions, and the rattle and bang and frequent breaking of clutches. It is durable and requires no repairs; it is compact and economizes room. It does not increase the pressure on journals when the speed is quickened, as is the case with belts running with great velocity, but remains constant at all speeds. And it will transmit any amount of power, even up to 100 horse power, with no greater percentage of loss, and with less pressure on journals than can be done by belts.

"It is not intended that this style of gearing should supersede the belt. There are hundreds of situations in which nothing can take the place of belts. The ease with which they can be carried almost in any direction, and to any reasonable distance, will perhaps always place them foremost as a means of transmitting power. But where several machines, that must be run independently of each other, and

be stopped and started without interference, are driven by the same motor, one connection at least should be frictional, and that, if practicable, should be the connection nearest the motor. Where the motions are slow and the occasions for stopping few, this is of less importance; but where the speed is considerable and the stoppages are frequent, it will be found a very great convenience.

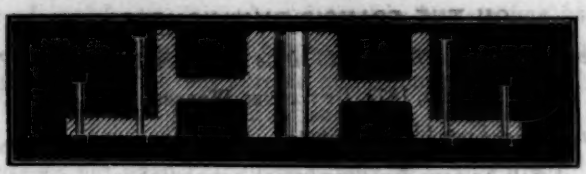
"Since the introduction of friction as a means of transmitting motion, it has often been desirable to apply the principle to bevel gearing. When correctly and substantially built and accurately put up, bevel and mitre friction wheels, within certain limits, operate just as well as those having cylindrical faces. In all fast motions, where not more than 10 horse-power are to be transmitted, the bevel friction is one of the best means of connecting at an angle. It may be adapted to almost any angle and change of speed. When required to give two motions in opposite directions, two equal bevel wheels facing each other may be secured to one shaft, and the third wheel matching, but not touching, yet placed on the end of a shaft, such that it may be brought into facial contact with either at pleasure.

"In building this gearing, the iron cone is made similar to a bevel pinion, but with a smoothly turned face, carefully finished and balanced.

"If not over 2½ feet in diameter, the driver may be built upon a 'hub flange'—a disc of iron of about two-thirds the diameter of the pulley, with a hub projecting from one side. The hub should extend one-half inch beyond the thickness of the wood to receive an annular disc of smaller diameter, through which the whole may be securely bolted together.

"Upon the flange, around the hub, the pulley should be built. The first two or three inches, to form the back, should be of hard wood, put on radially; for the other parts use soft maple, with the grain running as near tangentially as possible. The layers should be secured closely together with glue or white lead, and carefully and thoroughly nailed; after which the inner flange should be put on and the whole bolted together, and then truly turned to the exact angle and balanced.

"For a larger bevel driver it is best to use an iron center, with arms and a flanged rim of less diameter than the face of the wheel, to give room for the wood segments, thus:



"Upon this wheel the wooden rim is built as directed for the hub flange, except that the bolts must be put in as the work progresses, so that subsequent layers will cover the heads, and is finished without the smaller flange.

"In setting up this gearing it is of the utmost importance that the counter-shafts line exactly to the centers of the main shafts, and at the precise angle for which the pulleys were fitted, and that they are substantially set, so as not to get displaced.

"This gearing is thrown 'on' and 'off' by moving the counter shafts endwise in their bearings, This may be done by allowing the end of the shaft to extend through beyond the outer bearing far enough to receive an extra box, one end of which is closed and Babbitted to receive the end pressure. This box is set up by a lever to which it is pivoted. A groove in the end of the shaft where it is embraced by this box will serve to draw it back when the lever is released. In light work, it is as well to make the outer bearing answer for both end and side bearing, which may be moved in a line with the shaft.

"The pressure required to hold these pulleys up to the work is not great, and is easily applied by finishing the end of the shaft, and using a flat bearing of anti-friction metal, the full size of the shaft. Sometimes a steel point, like a lathe-center, is set against the end of the shaft to receive the pressure, but this is a very bad arrangement. It makes the bearing surface too small, and is one of the worst forms of bearing to keep supplied with oil. A flat bearing of wood, especially of hard maple, is very much better than this.

"When there is considerable difference in the sizes of bevel wheels working together, the end pressure is most upon the shaft carrying the larger; but this may frequently be neutralized, upon lines having several of these drivers, by setting them with their faces reversed.

"Facility of lever adjustment should always be provided."—E. S. Wicklin, *in Sci. Amer., April*, 1872.

ON THE FRANCIS DYNANOMETER.

A Paper read before the Franklin Institute at the Stated Meeting, December 18th, 1872, By Samuel Webber.

Gentlemen of the Franklin Institute:

Through the kindness of your President, I have the pleasure this evening of exhibiting to you an instrument for the measurement of power consumed by manufacturing machines and tools, commonly known as the "Francis Dynanometer."

The original of this machine was invented somewhere about the years 1836—7, by Mr. Samuel Batchelder, then agent and since Treasurer of the York Manufacturing Company at Saco, Maine, now living at Cambridge, Mass., one of the oldest living American cotton manufacturers, and differed from the present machine in delivering the power directly from the opposite end of the shaft to that on which the power was received.

As this mode of delivering not only reversed the direction of the power, but made it necessary to move the driving pulleys or the machine to make the connection, the second parallel shaft was added by James B. Francis, Esq., the agent and engineer of the Locks and Canals Co., at Lowell, thus restoring the direction of the transmitted power to the same line in which it was received, and making it practicable at once to place the dynanometer on the mill floor in the line of motion, and obtain readily the power required for any purpose.

The "dash-pot," or oil cylinder and piston, was also added to neutralize all jar and vibration, by preventing any sudden motion of the steel-yard, while the play of the piston in the cylinder is sufficient to admit of a slow motion with entire freedom.

The principle of the dynanometer is this: that of obtaining the "horse-power," or weight moved one foot per second, by suspending that weight to the end of a steelyard, which, were it not thus confined, would be free to rotate, and which would describe a circle of which its length is the radius.

The first shaft, passed directly through the axis of the steelyard, has fast on it, at one end, the driven pulley and a bevel gear, which forms one side of a compound or box gear.

The bevel on the opposite side and the delivering gear (which takes the place of the delivering pulley on the original machine) are fast on a sleeve or collar, which is caused to revolve in an opposite direction to the shaft by the two intermediate bevels, which complete the

compound, and which, being driven by the first gear, rotate freely around the steelyard, when no power is being transmitted, with the exception of such action as is due to the friction of the shaft and gears, which friction is ascertained and deducted in making a test of power.

The weight used on the original machine was 1 pound, and the length of the steelyard such (1·5919 ft., or 19 inches and a fraction) as to move the weight at its extremity 10 feet in one revolution, or 1,000 ft. in 100 revolutions; therefore 1 lb. moving 1000 ft. represented 1,000 lbs. moved 1 foot.

The present dynanometer, which you see was constructed by Hon. E. A. Straw, the Agent of the Amoskeag Company, at Manchester, N. H., and the present Governor of that State, on the same principle but by a different calculation; the two machines giving the same result in actual operation.

In this one, the steelyard is made the base of calculation, and is graduated in inches and tenths, each inch representing 100 lbs.

Starting at $6\frac{1}{2}$ inches from the centre to clear the frame, the graduation is carried out 20 inches, or to 2,000 lbs., and the weight obtained as follows: The extreme length is now $26\frac{1}{2}$ inches, thus being the radius of a circle of 53 inches diameter, or 166·504 inches circumference. This is 13·8753 feet described in one revolution, and the weight, to correspond to 1 pound moved 10 feet, is found to be ·7207 pounds.

Now this weight is only one-half of that required, for on the steelyard the action is that of supporting a weight supported at one end, and the weight is therefore doubled, making it 1·4414 lbs., or 1 lb. $7\frac{1}{16}$ oz. to represent 1,000 lbs. raised one foot in a second.

The poise or slide weight is obtained by a different calculation, as it is to represent 100 lbs. for every inch it is moved, and as a circle of 1 inch radius is 6·2832 inches in circumference, 100 times that circle is 628·32 inches, or 52·36 feet, and the weight to correspond with 1 lb. moved 100 feet, or 100 lbs. moved 1 ft. is found to be 1·9098 lbs., which, being doubled as before, gives 3·8197 lbs., or 3 lbs. $13\frac{3}{32}$ oz. nearly for the movable weight.

So much for the weights. The other element in the calculation is the velocity, which is obtained as follows:

A worm gear on the second shaft drives the clock by a pinion of one hundred teeth, and at every 100 revolutions rings a bell—the time of ringing being carefully noted by the observer—for such a pe-

riod as will enable him to fix accurately the time consumed in making 100 revolutions, whether it be 6 seconds, 13½, 19¼, 27, or whatever it may be.

The practical operation of the dynanometer is this: having carefully levelled it and secured it to the floor in the proper line of motion, a belt is brought from the driving pulley on the shaft to the first pulley on the dynanometer, and one led from the second pulley on the dynanometer to the main pulley of the machine to be weighed, and the whole put in motion. The action of the bevel gears immediately raises the steelyard, which is then weighted till it remains motionless in a horizontal position. This weight is noted, and also the number of seconds consumed in making 100 revolutions. The belt leading to the machine is then thrown off, and the weight required to balance the dynanometer in motion also noted and deducted from the total weight. The weight thus obtained is divided by the number of seconds consumed, and the result is the number of pounds raised 1 ft. in 1 second.

For instance, the following is the transcript of a test I have recently made.

A 9 in. circular saw, cutting inch board.

Saw, 4,000 revs. per minute.

Dynanometer, 100 revs. in 14 seconds.

Gross weight,	13,000 lbs.
Less bal. dynanometer,	400 "
Net weight,	12,600 "

12,600 lbs. divided by 14, gives 900 lbs. moved 1 ft. per second.

900 pounds divided by 550 lbs. gives 1·637 horse-power.

550 lbs. moved 1 ft. per second being the same as 33,000 lbs. moved 1 ft. per minute.

Mr. Francis has used the dynanometer in Lowell for many years, and copies of his machine are used at Dover, N. H., Clinton, Mass., and some other places in New England; and other dynanometers have been constructed on various plans, with springs and levers, but none which seem to be at once so accurate and easy of application.

With the increase of manufacturing and the decrease of water power in New England, a great interest has arisen to know the exact economical value of various machines and the results of improvements in them, and it is to make a test of one of these improvements, invented by one of your townsmen, that I have brought this dynanometer to Philadelphia.

The result may be briefly tabulated as follows, showing the power required for cotton spinning at various speeds, on $30 yarn.

Best Ordinary Ring Frame.			Garsede & Jenks' New Spindle.	
No. Rev. Sp.	Pounds per Sp.	Sp. per H. P.	Pounds per Sp.	Sp. per H. P.
5,000	5	110	2·65	205
6,000	6·30	87·30	3·45	159
7,000	8·80	62·50	4·55	121
8,000			5·75	96
9,000			7·23	76
10,000			8·00	64

Driving a spindle and a half more per horse-power at 10,000 revolutions than the old frame drove at 7,000.

The following tests, from my memoranda, will also show its application:

	Horse Power.
194 ft. 2⅛ shafting, 216 revs. per min., weight, with pulleys, 5·415 lbs., continuous oiling,	·687
186 ft. 2⅛ shafting, 211 revs., 5,335 lbs., tallow and oil,	1·442
Duplicate to the last, recently oiled,	1·234
9-inch circular saw above quoted, 4,000 revs, *pine*,	1.637
18-inch " " " 1·300 " *ash*,	1·273
1 small engine lathe, on 1 inch iron, heavy chip,	0·212
1 " " ⅜ " light "	0·092
1 cloth shear, 3 blades and fan, 2,000 revs.,	3·000
1 " 5 " " "	4·136
First shaft noted above, driving 20 looms on heavy ticking, additional for looms,	3·855
Or 5·18 looms per horse-power.	
10 looms on 36-inch sheetings,	1·084
Or 9·23 looms per horse-power.	

This machine was designed to test the power of any machine ordinarily used in a cotton mill, and I have obtained results with it covering the ground between 8-horse power and $\frac{22}{1000}$ of one.

It has been carefully verified by a long series of tests with a "Prony Brake," applied to a friction pulley 1 foot in diameter, substituted for the present driver, and found to register accurately the added weight, plus a small and uniform allowance for friction, which I assume to

correspond very nearly to the friction added to the shaft of a mill, when the belt is put on which carries the machine; at all events, nearly enough so to make the added measurements in detail correspond very closely with the gross result as obtained from the indicator of an engine or the calculated power of a water wheel of the best construction.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

A regular meeting of this Society was held at its rooms, in New York, on Wednesday afternoon, December 4th.

A paper upon "Rail Economy," by C. P. Sandberg, C. E., of London, in which—under the three heads, Iron Rails, Steel Rails, and Traffic Capacity—the author deals with the saving that may be effected in the item of railway cost.

Iron Rails.—The American demand for English rails of say 500,000 tons yearly, is unlikely to diminish soon. The late increased expense of iron adds to the cost of railroad construction, and tends to reduce the quality of rails. Welsh rails were often imperfect in weld; now they are sometimes also brittle. In the Cleveland district rail-making has greatly improved, chiefly by the increased application of fettling in the puddling furnace.

Still the buyers must guard against lamination and brittleness by tests for strength and wear, applied before the rails are laid.

Rails made of suitable iron, with a proper section, will not break in winter. In Scandinavia, with a climate more severe than in America, no accident has occurred from broken rails, though cross sleepers are exclusively used. But a very small portion of the iron rails shipped to America will stand the proper tests.

No late improvement promises so much to perfect iron rail-making as mechanical puddling, which now seems to be an entire success. Among the best appliances for this purpose are those of Danks and Spencer; one producing the whole charge in one ball, and the other in several small ones. By this improvement more rails can be made, at a reduced cost and of better quality.

Steel Rails.—The demand during the past year has been so great for steel rails that they can hardly be obtained at any price. The supply is limited by the lack of ore free from sulphur and phosphorus, and recourse has been had to extensive mines in Spain. It is

hoped that America will supply herself with steel rails, and import only those of iron required for new lines or light traffic. There is a scarcity of suitable ore for the Bessemer process throughout Europe, except in Sweden, which the recently discovered coal there will render more available.

The Siemens-Martin process of steel-making, superior to the Bessemer in requiring a less pure ore, has thus far produced so little that it can hardly be called a source of supply in the great market.

Steel rails are now so well made that they rarely break, except when the flange is punched, and this should be done only while the metal is hot, or the notch drilled and then slotted. Although a steel rail is generally thrice as strong as an iron one, when punched or the flange is cracked, the iron may be the stronger. The steel is made as soft as possible, say with $\frac{1}{2}$ per cent. of carbon, for not by hardness but by homogenity is it superior to iron. Usually a steel rail will carry one-fifth more dead load than an iron one; hence, for the same traffic, the steel rail, in comparison with the iron, should not be reduced in weight more than 20 per cent.

Buyers should require each rail to be permanently marked to indicate date, maker's name and quality, that subsequent use may determine which manufacture is best.

Traffic Capacity.—The amount of wear, or life of a rail, is usually expressed in tons passed over it before rejection; properly, the speed of travel should be taken into account, and 220,000,000 speed tons is a fair expression of the endurance of extra iron rail.

The average life of iron rails in England for ordinary traffic is about ten years; in and near London it is two years or less; on the Continent, from 12 to 15 years; and in Sweden, with less traffic than in England, from 15 to 18 years.

The weight passed over good iron rails before rejection has been found to average 10,000,000 tons. This may be taken to represent the life of extra iron rails, and six times that the life of good 56-pound steel rails. On the "London and North-western Line" steel rails have lasted twenty times as long as iron, and on the "Metropolitan Railway," where iron would not have lasted six months, steel will stand from three to four years.

In comparing the relative economy of superior iron rails and those of steel—prices of each per ton being taken at £7 and £11, and interest on capital 5 per cent.—the yearly saving per mile would be £4

where iron rails would last 15 years, and were used; £10 where they would last ten years and steel were used; and £78 where the iron rails would last five years and steel were used.

A table is annexed, showing the gross load in tons which each quality and weight of rail may be expected to carry during its life, and the conditions are stated therewith to aid in the selection of rail to accommodate a given traffic—an important matter, since many European railways are laid with too heavy rails, and American with too light ones. Equally important with the weight of a rail is a proper section. In England the double-headed rails are still generally used, and elsewhere in Europe the flat-bottomed pattern, as also in America. A specially bad section is the Erie 61-pound rail, which could be replaced by a 45-pound rail, well proportioned.

Prof. Rankin says the weight of the rails per yard in length should equal 15 times the greatest load on the locomotive drivers in tons. Perdonet, in France, takes 12 in place of 15. The writer, by adopting a section which permits a fish-joint stronger than the others in general use to be made, takes ten and less. Thus, for a 60-pound rail the weight on drivers is put at 6¼ tons.

Fish plates of steel will enable rail to carry from 15 to 20 per cent. greater load than if iron were used of the same section; they will cost per ton about £1 less than steel rails, and the iron about £1 more than iron rails; hence the adoption of steel fish-plates will be of benefit even with iron rails.

Mr. MACDONALD remarked that Mr. Sandberg, in taking 6¼ tons weight per locomotive driver as a safe load on a 60-pound rail, differs from the best practice in this country. The "Philadelphia and Reading Railroad," on rails made with great care by the company, prefers not to exceed four tons on a 64-pound rail, and the rail section has been gradually increased, to counteract wear and tear from even this medium load.

On the "Erie Railway," 5 4/10 tons weight on the drivers has been found too great for best 70-pound iron rails, and with a speed, for heavy freight trains, of 15 miles per hour, should not exceed four and a-half tons.

Mr. ALLEN remarked that this was of great personal interest to him. His first railway report dealt with the question of weight upon drivers, and showed the need of keeping it below certain limits. If greater weight is to be carried, the number of drivers should be in-

creased; and the time will doubtless come when locomotives with eight, ten and even twelve drivers will be used.

In no way has more money been wasted in the construction and operation of railroads than by the increasing weight upon drivers, to the great injury of road-bed, rails and rolling-stock.

A regular meeting of this Society was held at its rooms in New York, Wednesday evening, Dec. 18th.

"A Record of some Experiments showing the Character and Position of Neutral Axes, as seen by Polarized Light," by Louis Nickerson, C. E., of St. Louis, Mo., was presented and discussed.

During the researches of Eaton Hodgkinson, published in 1842, he took the ground that the neutral axis in a beam shifted as the load was increased, and finally took position where the compressive strength of the material above it would be equal to the tensile strength of that below it. He fixed this for a cast iron rectangular beam about to break at one-seventh its depth from the top, because its resistance to tension, was one-seventh that to compression, and this was apparently proved by an inspection of the fracture of beams which were broken. In 1855, Henry Barlow made experiments to test this theory, in the course of which he claims to have established that the neutral axis of a rectangular beam always lies through the centre of gravity of the section, and recognizes, in addition to the tensile and compressive elements of strength in a beam, a third, due to the lateral adhesion of the fibres, and increasing with the deflection.

Each takes the transverse strength of a cast iron beam at about $2\frac{1}{2}$ times as great as it should be, according to its tensile and compressive strength, and records a theory in regard to the character and position of the neutral axis, differing from the other.

The experiments here recorded were made to reconcile the results obtained by Messrs. Hodgkinson and Barlow, and to discover whether the "lamination of material in planes normal to the direction of the pressure excited upon it," was due to a periodic action of force, or consequent upon tangential stress, imperfect cohesion of the material, or the running together of internal cells. Polarized light was sent through plates of glass under compression, either as beams or columns.

The difference in the effects caused by similar strains on two materials is relative; and that produced by a force upon glass is like that upon other substances.

The results sought for are from certain general laws of the doctrine

of forces, which must be the same for all materials—and modified, not changed, by any particular one; the transparency of glass and its bi-refractive quality when strained exhibits them to the eye.

In the experiments, structural differences were ignored. Glass, cast iron and steel are amorphous bodies, yet composed of segregated crystals, and under pressure exhibit a similar characteristic fracture. There is also a like ratio between their compressive and tensile strengths—that of glass appearing to be a mean of the other two.

The apparatus used was the one common for experiments with polarized light; a polarizer of glass plates, an analyzer of one plate blackened at the back, and a small brass clamp with thumb-screw to compress the pieces of glass experimented upon, either as beams or columns. These pieces, before pressure is applied, appear black in polarized light—glass in an unstrained or neutral state being impervious to it.

A slip, representing a beam, placed in the clamp, and the screw slightly tightened, shows at the top and bottom a clear space, enclosing a dark space; between which, under greater pressure, take sharper outlines; and colored curves, distinct and separate, appear, following the lines of strain. These increase in number and brilliancy with the pressure, and always move towards the dark and neutral space.

The experiments were made in consecutive steps; the application of force ranging from proportionately a very small tensile with a very large compressive strain, to that where the two were nearly alike, and were described at length.

Colored drawings representing the effects of polarized light upon the various slips of glass experimented with, were exhibited.

The results obtained show that the neutral axis is a flexible line, or plane, truly parallel to the top and bottom sides of the rectangular beam and passing through the centres of gravity of its sections *only* when the load is evenly distributed from end to end, or when the beam is infinitely long; and that when there is a local pressure, the neutral axis is more or less governed in its direction and form, by the strain passing from the point of local pressure towards the points of support.

The beams of Mr. Hodgkinson were broken at the centre by a blow, in which the neutral axis was located above the centre of gravity of the transverse section. From these experiments it is deduced that this

position is due to the application of the force, and not to the ratio of the tensile to compressive resistance.

In comparison with Mr. Hodgkinson's, Mr. Barlow's beams were, in proportion of length to depth, one half longer, and he naturally found the neutral axis more nearly horizontal and less distorted.

Glass beams, in length fourteen times the depth, show the neutral axis so nearly horizontal that he may have overlooked the variation, and it must be almost imperceptible in beams more in length than ten times the depth.

It is claimed that the neutral axis, as exhibited by polarized light, from the cohesion of material or other cause, is extended to a breadth, and cannot become a true line, until, in reference to the cohesion, the tensile and compressive forces are infinite. Also that its longitudinal direction, like the directions of lines of strain, is not any arbitrary one, but resultant from the relative qualities and quantities of all the forces in the beam—its evident place in Physics being that of still water between opposing eddies or vortices.

The pulsations of completely polarized light are confined to two directions—at right angles to each other.

In the drawings are represented two images of the same object, corresponding to these two directions—one being taken, and the analyzer revolved 90° for the other; they, for convenience termed positive and negative images, are pictures of strains in the beam or column normal to each other. In the first tubular bridges, a wave of "buckling" always followed a line 45° from the top, where the load was placed, even crossing the stiffening plates. Such strains may be called "strut strains," and their resultant in a beam is vertical. The principal strains in an ordinary beam are horizontal or "flange strains" —being tension in the bottom and compression in the top. Their resultant is also horizontal and normal to the first.

The drawings show that when the "strut" or "flange" strains increase, correspondingly the negative or positive images, as the case may be, grow brighter.

Many strains may exist in the same beam, crossing and then neutralizing each other, and yet elsewhere be individual and intact.

As glass is pervious to polarized light when strained, and impervious when unstrained, the light parts must be strained in proportion to their brightness, and the dark unstrained or neutral; as bi-refraction is caused by strain, both must be governed by the same laws. Further: the resultant angles of the strains and those of polarization

are rectangles, and as the strains change in character, so do the polar images change in correspondence; therefore the images are pictures of the strains.

Any space which is under no strain, whatever load is applied to the beam, must remain dark under all revolutions of the analyzer; each marks the crossing of the two resultant axes, that of the "strut" and of the "flange" strains.

The appearance of light around the neutral band is the first symptom of distortion in the positive image; soon faint segments of yellow appear at the bottom, occupying a large part of the space between the supports, and at the top varying with the application of the load.

As the pressure is increased the yellow from both edges moves forward towards the neutral band, becomes a zone, and a segment of red succeeds. Both continue to move, until the red becomes a zone, and is followed by a segment of blue, between which and the red there is a dark neutral line.

A second similar series may be brought out before fracture.

Mr. Barlow established the existence of a third and important element of strength in a beam, which increases as the beam is bent. The moment of this or bending resistance is equal to that of the applied force or bending stress, and their common line moves towards the primary neutral axes as the load is increased. This is shown by the dark lines described.

There are then neutral axes existent, amidst disturbing forces, of a beam which under increasing loads shortens in the top and lengthens in the bottom.

A transparent column under pressure exhibits a series of colored rings, glass showing from three to six at each end, and a softer material, as copal, wreaths of colored bands from top to bottom, a dark space always occurring between the blue and red, which marks an unstrained part of the column, or a union of equal and opposite forces.

To determine what these dark rings indicated, tests were made upon columns, which changed in form under pressure. These were brass tubes, $\frac{45}{100}''$ exterior, $\frac{35}{100}''$ interior diameter, and about $1\frac{1}{2}''$ long.

Submitted to compression until they assumed a permanent form, they all exhibited from end to end a series of extended rings, uniformly separated, or periodic waves.

Other steel tubes, also compressed, were examined, and an empiric

expression derived which will locate any wave in relation to another, the tube being homogeneous.

Hollow columns, if sufficiently under stress, within elastic limits, may be greatly strengthened by bands, placed where the waves would otherwise occur. It is inferred that one-third additional material will thus double the strength of the column. In conclusion, the law of periodicity of force in compression, and probably in tension, seems to be proved, and the law of lamination under pressure accounted for.

Discussion.

Mr. Macdonald. The experiments upon which formulæ in common use for the proportion and strength of beams are based were made upon cubes of the materials tested, and it is found that the constants derived are inapplicable to ordinary cases in practice.

Mr. Boller. A recent comparison of various standard formulæ for the strength of beams, made by taking a given beam and calculating, with each formula, its safe load, gave as follows: Two, 25 tons; one, 30 tons; and one, 37 tons. The last was from Mr. Baker's formula, in which he has introduced the resistance due to flexion. The beam taken was 3″ x 6″, and 5 feet long. Engineers should know more of the strength of materials. The formulæ used involve the application of constants ranging variously from maximum to minimum strength. These often differ widely, and therefore give uncertain results.

Mr. Macdonald. It is known that a beam, loaded so that its outer fibres by formula should be under a maximum strain, will stand a greater load. The constants employed in calculating the strength of a beam should be determined from experiments upon a similar beam of the same material, and not those given for direct tension and compression.

Prof. De Volson Wood. The point of greatest interest to him in the paper read is whether the neutral axis is a line or a space, as water in an eddy.

In regard to the neutral axis and strength of beams, as determined by ordinary rules, the fact is we assume in a bent beam that the extensions and compressions are proportional to the distance of the elements from the neutral axis, and take the modulus of tenacity or of crushing, as the case may be, for the modulus of rupture of the beam.

A beam proportioned in accordance therewith will have an excess of strength.

Thus take a rectangular cast-iron beam, as the best example in practice. According to theory, the mean value of the modulus of rupture should be 16,000 lbs., but it is seen by experiment to be 36,000 lbs.

Former writers do not explain this discrepancy, but simply admit a defect in the theory.

Mr. Barlow detected a new element of strength, which he called "Resistance to Flexure," a term which is unfortunate, as all the forces in a beam which resist bending are resistances to flexure. "Longitudinal Shearing Resistances" is a better term, and one now used.

This force is the resistance of the fibres to being drawn over each other. If there was no such resistance the fibres would retain their original length.

He found, by a critical examination of iron beams, that the traverse sections remained normal to the neutral axis during flexure, thus proving the existence of a force besides that which produces direct elongation and compression.

This is the longitudinal shearing resistance. Mr. Barlow also determined the laws governing it at rupture, and modified the formulas accordingly.

His experiments are the most weighty and valuable of any made upon beams, as far as theory is concerned. His formulas and constants agree with the actual strength for all sections which he used.

It is evident the ordinary law, that strains vary as their distance from the neutral axis, cannot apply to beams of ⌶ section; for, that it may apply, there must be at least a continuity between all the elements of the flanges and the web.

Mr. Barlow's formula for this case cannot be correct. In all ⌶ sections there is a peculiar combination of the strains about the angles where the flanges and web join.

Prof. Norton, by direct experiment, determined the fact of a transverse shearing resistance in beams, and the laws governing it in those of rectangular section. The deflections due to longitudinal and transverse shearing resistances tend respectively to diminish and increase that defined by Navier's theory.

Simple rules cannot be given applicable to the varied forms of beams in use. Constants deduced from experiment upon solid rect-

angular beams will doubtless apply to solid beams of all dimensions, but not to others.

Mr. BOLLER. It is best to make a beam proportioned similar to those to be used, break it, and deduce therefrom a constant.

The formulas for H beams are safer for thin than thick webs; say ¼″ web, and 4″ flange.

Prof. WOOD. The experiments of Baron Von Webber showed that the web had never been made too thin. Where the flange and web are joined there should be a large curve.

Mr. MACDONALD. In T. C. Clarke's description of the Quincy bridge there is a statement that 12-inch H floor beams, 15½ feet long, suspended in pairs from panel points about 12 feet apart, and carrying a single track of 4′ 8½″ gauge, scarcely deflected under a maximum engine load, which caused a strain upon the outer fibres at least equal to 14,000 lbs. per square inch, according to formulas in general use.

Prof. WOOD. Structures should not be proportioned in reference to the ultimate strength of the parts, but their elastic limits. Some very tenacious irons have a low limit of elasticity; while in other cases—certain grades of steel, for instance—elasticity is preserved under a strain equal to one-half the tensile strength.

The Secretary presented communications upon Mr. Nickerson's paper, from Gen. Barnard, Col. Merrill, Messrs. McAlpine and Fuertes, reading of which and further discussion were deferred until the meeting to be held February 19th next.

Influence of Pressure on the Spectra of Gases.—A foreign contemporary publishes the following information as an observation of M. Cailletet: When a spark from an induction coil is passed through a tube containing a gas under ordinary pressure, the light is feeble and presents in the spectroscope very indistinct bands. But if the pressure be slowly increased, the bands will become brighter and broader, producing in the end a continuous spectrum. Upon reaching a pressure of two hundred atmospheres the electric current ceases to pass.

REPORTS UPON THE TESTS OF THE WORTHINGTON PUMPING ENGINES—AT BELMONT.

Report of Experts and Engineers appointed to test the duty and capacity of the Worthington Pumping Engines at Belmont.

To the Select and Common Councils of the City of Philadelphia:

GENTLEMEN:—The undersigned, appointed by your honorable bodies to test the Worthington Pumping Engines at Belmont, beg leave to present the following report:

On examination it was decided to test Engine No. 2, which has been in operation during the past twelve months.

The tests were of two kinds.

First. The duty test, by which is meant the ability of the engine to perform a given amount of work, and is expressed in pounds raised one foot high with one hundred pounds of coal.

This test takes into account the actual resistance against which the engine works, is calculated from the known dimensions of the pump, the observed pressure in the pump main, and speed of engine, and is independent of the actual delivery of water into the reservoir.

Second. The capacity test, or actual discharge at the reservoir.

This is expressed in cubic feet or gallons, and the amount by which this falls short of the theoretic or calculated capacity of the pumps, represents the leakage through the pump valves, around the plunger, through joints, &c.

For the purpose of bringing the whole work within the period originally assigned, forty-eight hours, the two tests were conducted at the same time; observations of the delivery at the reservoir being conducted whilst those connected with the working of the engine were being made.

DUTY TEST.

Previous to the test, the pressure gages were carefully compared with standard test gages, and a certified statement of their variations obtained. The coal scales were tested and sealed by the official sealer of weights and measures. The pressure gages on the engines indicated the resistance, measured from the centre of the gage to the delivery in the reservoir. A float and gage rod marked the level of the water in the pump well. The whole resistance, or load, on the engine, therefore, is expressed in feet, by adding the height due to the indicated pressure on the gage to the vertical distance from the centre of the gage to the level of water in pump well. The

counter attached to the engines indicated every fourth stroke, and the reading was noted every half hour by actual count of the strokes.

The feed water for the boilers was accurately measured in a tank of ascertained capacity, and charged to the boiler as delivered. The correctness of the manner of measurement was verified at the commencement of the test.

The coal consumed was carefully weighed, one or more assistants being on duty in the fire room during the whole test, and having a constant supervision thereof.

Half-hour observations were taken of the engine counter, the indicated water pressure, height of well gage, steam pressure at engine and boilers, speed of engines, length of stroke, condition of vacuum, and temperature of feed water. These observations were made by not less than three persons at the same time, and their notes carefully compared and verified as the test progressed.

The measurement of feed water was constantly in charge of an assistant, and every separate charge of water to the boilers was entered in a book kept for the purpose.

The fires were carefully observed at commencement of test, steam in boilers being at forty-eight pounds pressure, and water in glass gages standing at two and one-half inches.

The test commenced at 4·40 P.M., on Wednesday, May 15th, and continued until Friday, May 17, at 5 o'clock P. M., being of forty-eight hours and twenty minutes duration.

Summary of Result.

		Hours.	Mins.
Duration of test,		48	20
Reading of counter at close of test,	959273		
" " " commencement,	924372		
Number of strokes as per counter,			34901
Counter indicating every fourth stroke	34901 × 4 =		139604
Average stroke per minute,			48·139
Diameter of water plunger in inches,			22·5
" " piston rods "			4
Mean area of plungers in inches,			391·33
" length of stroke,			49·347
Displacement of plunger in cubic inches,			19·311
" " " gallons,			83·6

Displacement of plunger in (water at temperature of 66° = 62·297 pounds per cubic foot),			696·2
Mean water pressure, in pounds, per sq. inch,			86·724
Height due to this pressure, in feet (water at 66°),			200·46
Distance from centre of gage to water in pump well, in feet,			17·28
Total height, including frictional resistance, in feet,			217·74
Average steam pressure at boiler, in pounds, per sq. in.,			48·85
Average steam pressure at engine, in pounds, per sq. in.,			46·66
Vacuum at engine, in inches,			26.5
Average temperature of feed water, degrees, Fahr.,			129·59°
Coal charged to boilers, in pounds,		40330	
Ashes and clinkers,	4349		
⅓ of this available for firing,		1450	
Correction of weight to raise water at,		38880	
Close of test to original level,		10	
Total coal for work of engine,			38890
Water charged to boilers, in cubic feet,		5212	
Less leakage (temp. 138°, weight 61·52 pounds per cubic foot),		40	
			5172
5172 cubic feet × 61·52 pounds	=		318181
Loss of water in boiler during test, pounds,			530
Total water evaporated in pounds,			318711
Pounds of coal to evaporate this amount of water,			38880
Evaporative power of boilers, $\frac{318711}{38880}$	=		
pounds of water, with one pound of coal,			8·19

The correction of weight of coal is obtained in this way. At the close of the test, the water in boilers was 0·17 inches lower than at commencement. The engine is therefore charged with coal sufficient to bring the deficiencies of water (530 pounds) from 130°, the temperature of feed water, to temperature of steam, at 48 pounds, 295°·07, or 10 pounds of coal.

On the other hand, by reason of this deficiency, the boilers had evaporated so much more water than appeared to be delivered to them, and had done it without the use of this additional ten pounds;

consequently, 530 pounds has been added to the weight of water delivered by the feed pump.

The duty of the engine is thus calculated.

Duty calculated from actual evaporation—

Displacement of plunger in pounds per stroke.		Stroke of engine in hours & minutes. 48 20		Height of delivery in feet.	
696.2	×	139·604	×	217·74	× 100 =

38890 pounds of coal.

54,416,694 pounds raised one foot high with 100 pounds of coal, being in excess of the guaranteed duty, 8·83 per cent.

On the basis of an evaporation of 9½ pounds of water, with one pound of coal, which the contract with Mr. Worthington allows, the duty would be 63,120,707 pounds, or an excess of 26·24 per cent. over the contract requirement.

Capacity Test by Weir.

The quantity of water discharged at the reservoir was measured over a Weir, carefully constructed under the direction of Mr. T. H. Risdon, a gentleman practically acquainted with this mode of measuring water. Under his directions also the observations and calculations were made. From these it appeared that the pumps delivered into the reservoir, in 48 hours and 20 minutes, 1,500,584·52 cubic feet of water, equal to 11,225,122 gallons, or at the rate of 5,573,853 gallons in 24 hours; being 11·47 per cent. in excess of 5,000,000 gallons guaranteed by the contract.

The discharge of the pumps, calculated from the displacement of the plungers, was 5,795,200 gallons in 24 hours, being more than that determined by Weir measurement by 3·8 per cent.

It will not be correct to assume that the whole of this difference is due to leakage by and through the pump, and in order to ascertain as nearly as possible the amount due to that cause, it may be observed that during the whole test some portion of the injection water for the condenser was taken from the pump main, the suction injection at the high temperature of the river not furnishing sufficient. This quantity was not less than one hundred gallons per minute, which would make the loss by leakage through the pump not exceeding 1½ per cent.

The tests, both of capacity and duty, have been made with great care, and every precaution taken to obtain a correct result.

The conclusion from the facts and figures given is that the engines are fairly and easily performing a duty considerably beyond the guarantee.

The engines worked during the whole test with remarkable smoothness and precision, with scarcely a perceptible variation of speed or length of stroke, and the character of workmanship throughout appears unexceptionable.

JACOB G. NEAFIE,
HENRY L. HOFF,
W. BARNET LEVAN,
GEO. H. BAILEY,
ISAAC S. CASSIN.

May 31, 1872.

Report of the Expert selected by the Citizens' Committee of Thirty, upon the Trial of the Belmont Pumping Engines.

It will be remembered that Henry P. M. Birkinbine was selected by the Committee of Thirty of the Citizens' Municipal Reform Association to represent them at the test of the engines of the Belmont Water Works. The following is a complete copy of the report which he has made to the Committee:

JAMES DOUGHERTY, Esq., Chairman of the Committee on Water, Citizens' Municipal Reform Association:

DEAR SIR,—When your note of May 10th was received, informing me of my selection as expert for the Citizens' Municipal Reform Association, in the test of the engine and pumps at the Belmont Water Works, I communicated with the members of the Committee previously appointed by the City Councils. At that time all the preliminary arrangements had been made, the engines, pumps and boilers had been thoroughly overhauled and cleaned, and the committee had examined the engines and pumps when they were taken apart, being unanimous in reference to the integrity of the workmanship of the machinery. So far as I was able to judge, the construction of the engines is satisfactory.

The arrangements were made to commence the test on May 15th. Before noon that day all parties were represented, and the test was commenced at twenty minutes to five P. M., being continued until May 17th, at five o'clock P. M., a period of forty-eight hours and twenty minutes.

The engine was handled in a masterly manner by Mr. Jenkins, foreman of the works where the engine was built, assisted by Mr. Root, who set the engine up, and by the city engineers on duty at the works.

The following memoranda of parts of the engine and boilers were furnished me:

Steam was generated in six (6) boilers, each having two (2) mud-drums attached.

Diameter of boilers, 54 inches.

Length of boilers, 30 feet.

The convex heads increase the length of the boiler at the centre to 30 feet 10 inches.

Diameter of mud-drum, 28 inches.

Length of mud-drum, 22 feet.

Total grate surface, 264 square feet.

Total heating surface—

In boilers,	1479 square feet.
In mud-drums,	1969 square feet.
	3448 square feet.

Compound Duplex Pumping Engine—Diameter of high-pressure cylinder, 29 inches.

Diameter of low-pressure cylinder, 50¼ inches.

Diameter of pump-plunger, 22½ inches.

Diameter of piston-rod of pump, 4 inches.

Travel of piston between cylinder-heads, 50 inches.

Average displacement of pump-plunger, per stroke of 48 inches, 81·315 gallons.

Height of lift from water in Fairmount dam to overflow of reservoir, 208·03 feet.

Pumping main, 30 inches in diameter.

Pumping main, 4167 feet long.

In conducting the tests, observations at the engine-house were made every thirty minutes, and carefully recorded.

First. Of the pressure of steam in the boilers. This was maintained at an average of 48·85 pounds, never falling below 48 pounds, and reaching 50 pounds at but one observation.

Second. Of the pressure of steam at the engine gauge. This averaged 46·66 pounds, never falling below 45 pounds nor exceeding 47·5 pounds.

Third. Of the vacuum in the condenser. This was maintained nearly uniform at 26·5 inches, varying but 0·25 of an inch. As the

plunger displacement was to be considered as the capacity of the pump, I inquired if water for condensing the steam would be taken from the ascending main, and was assured that it would not be done. After the test was well under way, water for condensing steam *was* drawn from the ascending main, as the engineers in charge stated that otherwise it would be impossible to maintain the vacuum. To this I objected, as an engine constructed so that a part of the condensing water had, under ordinary circumstances, to be drawn from the main, under a pressure of over 200 feet, is in that respect defective.

The temperature of the water was 66°.

The amount of water thus taken from the ascending main is impossible to determine.

Fourth. Of the guage on the delivery end of one of the pumps. This averaged 86·724 pounds, but, as the index vibrated from five to eight pounds at each stroke of the pump, the readings were necessarily imperfect. The pressure indicated by the gauge is probably greater than the actual pressure due to the height of the lift above the gauge (190·75 feet), and the friction on the ascending main. Taking the average reading of the gauge as correct, and adding the height of the gauge above the water in the pump well, the lift will be equal to 217·74 feet.

Fifth. Of the number of strokes. The average was 48·138 strokes per minute; never by count falling below 47, and in but two instances observed increasing to 50.

Sixth. Of the length of stroke. When the engines were started, before the test began, the stroke was about 48 inches, which the city's engineer in charge reported was the ordinary stroke of the engine. This allows one inch at each end for clearance, to meet an emergency, such as an increase of steam pressure, or the imperfect closing of the pump-valves.

By an arrangement of valves the stroke was increased to 49·25 inches, when the test began, and after four hours it was worked up to 49·375 inches, being maintained at the same stroke for most of the test, never falling below 49 inches. The average during the entire test was 49·347 inches.

To this increase of stroke I made objection, as it caused the engine to be worked in an unusual manner, and increased the capacity of the pumps 2 $\frac{74}{100}$ per cent., without requiring any more steam than was necessary to make the ordinary stroke of the engine, thereby augmenting the duty.

Seventh. Of the amount of feed-water. This water was supplied through a measuring tank graduated to 20 cubic feet; 19 cubic feet was the usual charge. When this was pumped out, the tank was replenished. The total amount of water suppled to the boilers was 5212 cubic feet. A leak discovered in the feed-pipe, which was estimated to have lost 30 cubic feet, reduced the amount of water evaporated to 5172 cubic feet, or 318,181 pounds.

The average temperature of the feed-water as it entered the boiler was 133°.

At the end of forty-eight hours the level of the water in the boilers was found to be 0·75 of an inch lower than when the test began.

This will increase the amount of water evaporated 48·13 cubic feet, or 2961 pounds; but as the water was simply converted into steam in the boilers, it was at a great saving of fuel over that supplied from the feed.

The total amount of water evaporated was, therefore, 5220·13 cubic feet, or 321,142 pounds.

Eighth. Of the coal consumed. The coal for the test had been carefully selected, screened, picked and stored in the boiler-room.

At the commencement of the test steam was at 48 pounds, the fires in proper condition, and water 2½ inches in the glass gauge.

Eighteen hundred pounds of coal were weighed and delivered in front of the boilers. When this was burned another charge of 1800 pounds was weighed out: this was continued until the close of the test, except the last two charges, when but 1200 pounds was taken for a charge.

The amount of coal perceptibly fell off towards the close of the test. Attention was called to the fact that, the conditions remaining the same, there could be no difference in the amount of fuel required to do the work toward the close of the test or at any other period during the time.

And, while at the termination of the test the fires might apparently be as good as at the commencement, they could not possibly be of the same intrinsic value. That this position is correct is evident from the fact that, during the entire test, 0·287 of a pound of coal was consumed per stroke of the engine; that during the first 40 hours, 0·3118 of a pound of coal per stroke was used, and during the last 8 hours and 20 minutes but 0·171 of a pound of coal per stroke was consumed. As there was no change in the work done, there must have been a

deficiency in the amount of coal. This deficiency, estimating the last 8 hours and 20 minutes, to require the same amount per stroke as was consumed per stroke in the entire test, will be fully 3035 pounds.

The total amount of coal consumed under the boilers was 40,130 pounds, and the total amount of ashes, clinker and unburned coal taken from the ash-pit was 4349 pounds. A portion of this was screened in a sieve and picked, the amount of unburned coal being estimated at 1450 pounds, which was deducted from the coal burned. Objection was made to this.

First. Because the coal used was not ordinary merchantable coal, as it should have been, but had been carefully cleaned of all foreign matter, as is evident from the small amount of refuse, less than 11 per cent., the usual allowance of merchantable coal being 20 per cent.

Second. Because the small amount of unburned coal had no commercial value.

The deficiency of feed-water, amounting, as before explained, to 2961 pounds, would have required at least 357 pounds of coal additional had it been supplied from the feed instead of steam being generated from the water contained in the boiler.

The engine should therefore be charged with 40,130 pounds of coal burned under boilers, 3035 pounds of coal deficiency in quality of fire, 357 pounds of coal deficiency in water; total, 43,522 pounds.

Ninth. Of the evaporating power of the boilers. The total amount of water evaporated during the entire test, with the loss of water in the boilers added, was 324,103 pounds. This divided by the coal chargeable to the engines, will show that the boilers evaporated 7·447 pounds of water by the consumption of one pound of coal. This is certainly very satisfactory working evaporation. The contract for the engine specifies that unless the boilers evaporate 9·5 pounds of water with one pound of coal the engines are to be credited with the difference. As the results contemplated by this clause of the contract are rarely if ever achieved in practice, it certainly cannot be considered in the calculation of working duty of the engine.

Note. Wicksteed, in a table of results of the evaporating power of different boilers, shows 8·687 pounds to be the best recorded result. See "An Experimental Inquiry concerning the Cornish and Bolton and Watt Pumping Engines," &c., by Thomas Wicksteed, London. James Weale, table No. 5, column 21.

Chief Engineer Isherwood, United States Navy, in his experiments at the New York Navy Yard, upon the comparative evaporative efficiency of coal, gives 4·7039 as a fair average, and a waste of 20 per cent. in ashes, fine coal, &c. See "Engineering Precedents," Vol. 2, page 37.

In the experiments made by the American Institute last fall, the average actual evaporation per pound of coal, with different boilers in competition, was found to vary from 7·07 to 8 pounds. See "Journal Franklin Institute," No. 557, page 389.

Tenth. Indicator cards were taken from the high-pressure cylinder, the low-pressure cylinder, the delivery side of the pump, and the pumping main immediately at the pump.

These show that the steam is not used expansively in the high-pressure cylinder; that the principal work of the low-pressure cylinder is that done by the vacuum produced by the condensation of steam; the increased area of this cylinder is its great advantage; that so far as the steam end of the machine is concerned, no marked economy is possible. The pump card is perfectly satisfactory, showing a remarkable uniformity of pressure the entire length of the stroke; the actual delivery of the pump must be nearly equal to the calculated displacement of the plunger; the amount could not be ascertained, as a portion of the condensing water was taken from the ascending main, as above stated.

Eleventh. Of water flowing into the reservoir. This was measured by passing it over a weir, arranged to use the formula of J. B. Francis, civil engineer. A hook gauge was used. It was graduated to read to the one-thousandth of a foot, and the readings were taken every five minutes. These measurements may be relied upon as correct, and are as follows:

First twenty-four hours, . . .	5,584,926 gallons.
Second twenty-four hours, . . .	5,559,318 "
Twenty minutes, ...	71,124 "
Total, ...	11,218,368 "

The total number of strokes during the test was 139,604, and the actual amount delivered into the reservoir 80,358 gallons per stroke, a loss of 3·242 gallons per stroke, probably used for condensing steam.

The above statement exhibits the fact that the test was conducted to show the utmost that can be done by the engine under the most favorable circumstances. The results must, therefore, be considered as theoretical when calculated in accordance with the contract as interpreted by the committee appointed by City Councils, for they do not exhibit the fair working value of the engines, fired with merchantable coal and run as under ordinary circumstances.

It would be manifestly unjust to take an experimental result like the above as a standard of comparison for the economic working of this class of engine.

Charging the engine with the amount of coal burned, and that necessary to make up the deficiencies as above, 43,522 pounds, and crediting the engine with the actual work done, viz., raising 93,485,513 pounds of water 208 feet, will give an actual working duty of 44,679,000 pounds.

That this estimate is correct is evident from the calculations made of the average duty of these engines during 1871, taken from the report of the Chief Engineer, page 20. This gives 37,970,173 pounds, or, from calculations made from records kept in a book in the engine-house of the work done during the previous month (April), when the average duty was 39,232,500.

While the engines as tested and calculated meet the requirements of the contract, they are below the representation made to Councils before the contract was made, namely, 67,969,000 pounds as an average annual actual duty.

It is but justice to the builders to say of the engine tested, that it is not only well built but operates smoothly and regularly, and is fully up to the guaranteed capacity, but not to the duty.

Respectfully submitted.

HENRY P. M. BIRKINBINE.

June 6th, 1872.

New Material for Moulding.—M. Müller describes in a French contemporary a process of forming ornamental and useful objects of pure silica. His process consists in obtaining the silica in form of an impalpable powder—(probably by precipitation)—which is then formed into a paste and moulded. The form is then heated to bright redness, when the grains fuse together, become very coherent and form objects of great durability.

Chemistry, Physics, Technology, etc.

BIELA'S COMET AND THE METEORS OF NOVEMBER 27TH.

By Professor Daniel Kirkwood.

The fact that comets on their approach to the sun have at times undergone the process of dissolution is abundantly sustained by recorded observations. The latest and most remarkable instance of such disintegration is that of Biela's comet. This body completes its revolution about the sun in a little more than six years and eight months. Shortly before its perihelion passage in January, 1846, it was seen to separate into two distinct fragments. Astronomers, anxious to see whether the parts had remained separate during an entire revolution, awaited the return in 1852 with more than ordinary interest. The *two comets* appeared at the predicted time; their distance from each other having increased to more than five times that of the moon from the earth.

At the next return, in May, 1859, both comets escaped detection. This was attributed solely to the fact that the relative positions of the comets, the earth, and the sun, were unfavorable for observation.

It will be noticed that three periods of the comet are very nearly equal to twenty years. Hence the perihelion passage of January, 1866, like that of 1846, was in circumstances favorable to telescopic scrutiny. A diligent watch was maintained during several weeks for the expected wanderers: the search, however, was without success. It was accordingly inferred that the same cause which had produced the bi-partition in 1845 had occasioned a still further separation, so that the dissevered fragments had become invisible. The comets were again due in September, 1872, but escaped, as before, the most powerful telescopes.

The orbit of the original comet intersected that of the earth at the point passed by the latter about the 29th of November. A collision of the two bodies was therefore inevitable in case they should both reach this point of intersection at the same time. To quiet the apprehension of such a catastrophe, M. Arago showed that a collision could not reasonably be expected for thousands or even millions of years to come. It is evident, however, that the probability of impact must be vastly increased by the disintegration of the comet and the diffusion of its fragments around a considerable arc of the orbit. Now, as it is well known that the comets connected with the meteoric streams of August 10th and November 14th have been for many cen-

turies in the process of dissolution, it is altogether probable that the breaking up of Biela's comet did not commence with the *visible* separation in 1845. Analogy therefore led astronomers to expect the appearance of meteors—the products of disintegration—about the last of November. The fact was noticed several years since that a considerable number of meteoric stones had fallen at this epoch. It is also known that a shower of falling stars was observed in France on the 29th of November, 1850.

Now as the greater part of the matter which constituted the comet of Biela must have passed the earth's orbit (in 1872) but a few weeks previous to the earth's arrival at the point of intersection, it seemed not improbable that parts of the cluster might still be passing during the last days of November. Professor Newton, of Yale College, actually detected these straggling fragments on the evening of November 24th, 1872. During five hours he counted 250 meteors, over three-fourths of which radiated from Gamma Andromedæ. A more remarkable shower, however, was observed in Indiana on the evening of November 27th. Professor Joseph Tingley, of Greencastle, counted 110 in forty minutes. This would give 165 per hour for one observer. But according to Professor Newton, the whole number visible at any station, when the sky is entirely clear, is five times the number seen by a single observer. The enumeration by Professor Tingley accordingly indicates an actual fall of 825 per hour. At Princeton, Indiana, Professor D. Eckley Hunter, with assistants, counted 70 meteors in thirty minutes; the position of the observers being such that more than one-half of the sky could not be seen. Again on the evening of December 3d, at about 10½ o'clock, an extraordinary meteor was seen at Bloomington, Indiana. Its apparent magnitude was estimated at one third that of the full moon. Its light, which was of a bluish tinge, illuminated, like a flash of lightning, all objects on which it fell. It appeared a little North of East, at an altitude of about 35°, and the direction of its motion was nearly conformable to the radiant observed by Professor Newton on the 24th of November. It seems therefore not improbable that it may have been a straggling member of the same group.

As the meteors of this cluster are doubtless the *debris* of Biela's comet, if we find the epoch at which the original body would have crossed the earth's orbit *near* the 29th of November, we may regard the collision of our planet with some of the large fragments—and hence a grand meteoric display—as highly probable at the same period. An easy calculation, which need not here be repeated, gives

the last of November, 1892, as such an epoch. The phenomena will doubtless be looked for with a very lively interest.

Bloomington, Ind., Dec. 5th, 1872.

BITUMINOUS COAL; ITS ORIGIN, VARIETIES AND A FEW OF ITS SPECIAL USES.

The substance of a paper presented at the Dubuque Meeting of the American Association for the Advancement of Science.

By E. B. Andrews, of the Ohio Geological Survey.

(Continued from page 69.)

In the ooze the *Stigmaria* almost reveled, penetrating it in every direction, and these curious vegetable forms with their spreading rootlets are bound in the greatest abundance in cannel coals, all flattened but in exquisite preservation. The existence of so many *Stigmariæ* in the cannel coals, the beds of which extend often for many miles, almost necessitates the conclusion that they grew *in situ*. If the *Stigmaria* is always a true root of *Sigillaria*, or other tree, as held by Dawson and others, we must conclude that trees, having their roots attached, grew in the wettest parts of the marsh, which were, therefore, not open lagoons as some have supposed. But Dawson asserts that "*Sigillariæ* grew on the same soils which supported Conifers, *Lepidodendra*, *Cordaites* and ferns, plants which could not have grown in water." He also claims that most of the underclays which, so far as I know, universally contain rootlets of *Stigmariæ* "are, in short, loamy or clay soils, and must have been sufficiently above water to admit of drainage."

These views require us to believe that the *Stigmariæ* could not have grown where they are found in cannel coal, but were floated to their present places as detached fragments.

If thus floated we should expect that they would show sometimes local accumulation on drifted heaps. So far as my observations go, they are very evenly distributed over the whole cannel coal area. Moreover, if detached and floated bodies and afterwards buried in the accumulating mud, we should naturally expect them also to go to decay and form vegetable muck similar to the surrounding mass. On the other hand, Lesquereux, Goldenberg and others hold that the true *Stigmaria* was an aquatic plant. Lesquereux thus writes: "It is my belief that the genus *Stigmaria* does not represent tree roots, but floating stems, of which species of the genus *Sigillaria* constitute the flowers or fruit-bearing stems." It was, if I understand his views, only under favorable circumstances that these stems prodeced the

stalks, or more properly trunks, by which the fructification was secured. By this theory it is certainly more easy to explain the vast number of *Stigmariæ* found in cannel coals. By it we may perhaps also account for the equally great numbers of *Stigmariæ* found in some of the sand rocks of the lower Coal Measures of Ohio, in which *Sigillariæ* are but seldom found. Since we often find *Stigmariæ* in the bituminous coal the "floating stem" theory would harmonize with the other opinion of Lesquereux, arrived at after careful study of modern marshes and peat-bogs in Europe and America, that the coal was formed in similar marshes, skirted by the ocean, which would furnish the needed conditions for the growth of such aquatic vegetation as he regards the *Stigmariæ* to be. With the questions of physiological botany involved in the determination of the generic affinities of this strange plant I have nothing to do; they belong to the palæobotanists. Schimper, in his great Work on *Vegetable Palæontology*, after giving the views of different authors, says, "We conclude that, admitting the radical nature of the *Stigmariæ*, we remain still very doubtful as to their generic determination, and still more as to their specific reference."

In a seam of coal, which I traced for many miles in West Virginia, the coal in one locality is chiefly resinous and bright, further on it passes into a dry splint, and at other points changes into cannel. At one place the vegetable mud, which formed the cannel, was deposited upon a floor of accumulated vegetable matter which now constitutes a layer of splint coal. This mass of vegetation had had its day at the surface when that surface was much dryer, but had afterwards sunk in the depression of the marsh which formed the muck basin. In another place the cannel coal has over it a layer of splint. In the latter case the condition of things in the original forming period would resemble that of some of our present marshes, where we find the vegetable ooze below, covered by a quaking surface of growing vegetation, including, sometimes, trees of considerable size. If such a marsh were buried under a heavy mass of sedimentary matter, and chemical reactions were to take place similar to those of the coal era, we should have something akin to cannel coal below, and above, either a highly bituminous or splint coal as the case might be.

These general views of the origin of cannel coal I give because they are the results of independent observation on my part. Other geologists have expressed views essentially the same. Lesquereux, who has given much attention to peat bogs and other forms of marshes and their vegetation, has stated that "cannel coal has been formed

under water from more decomposed vegetables." Dr. Newberry long since declared that cannel coal was formed from finely macerated vegetable tissues accumulated as a carbonaceous mud. Dawson attributes cannel coal to "vegetable mud," and his view is endorsed by Sir Charles Lyell.

Ashes in Coals. The variation in the percentage of ash in coals is very great. It may arise from these causes: First, the coals may have been formed from different kinds of vegetable tissues, which themselves contained varying quantities of ash. It is well known that the different parts of a modern tree, the bark, wood, leaves, &c., give different amounts of ash. Hence coal formed from different parts of the ancient vegetation would doubtless show similar differences. The least ash found in any Ohio coal is 0·77 per cent., and another sample, from the same part of the same seam at another location, a mile or more away, gave 0·85 per cent. These samples contained a very large amount of mineral charcoal, more than I have ever found in any other seam of coal. No examination by the microscope has been made in this case to determine what parts of the plants have formed the mineral charcoal. Dawson has found in the mineral charcoal of the Nova Scotia coals *fast tissues* from the inner bark of *Sigillaria* and *Lepidodendron*, especially of the former, *discigerous wood vessels* and *scalariform vessels* of the same and other forms of plants, *vascular bundles of ferns* and *epidermal tissues*. It is probable that the more woody matter of the trees constituted no inconsiderable part of the usual mineral charcoal, and the ash of this would be less than that of coal formed more completely from leaves and from the costical layers. Samples for analyses selected with great care might determine this point. Second, the quantity of ash would be in proportion to the waste and decay of the vegetation. The ash or inorganic matter of the plant would remain and accumulate, while, in the decay, the organic portions might be entirely dissipated, as is seen in the rotting of wood in our forests at the present day. The more extensive and longer continued the decay, the larger the amount of ash in the final residuum of coal. Third, the ash is increased by the deposition of sediments from overflows of the coal-marsh by muddy waters. The sediment would become intimately mixed with the whole vegetable mass. In some seams of coal we find these sediments so exceedingly fine that they leave a film upon the horizontally accumulating laminæ thinner than the most delicate tissue paper. Sometimes these sediments are so great as to make the ash excessive and the coal practically worthless. In the ordinary

bituminous coals of Ohio Prof. Wormley has found the average ash of 88 samples from south-eastern Ohio to be 4·718 per cent., and that of 64 samples from north-eastern Ohio to be 5·120 per cent.

The quantity of ash in cannel coals has a very wide range of variation. This might be expected, for the shallow water, standing perhaps a good part of the time in the places where cannel coal is formed, would be an almost constant bearer of sediments, especially if such shallows had openings, wider or narrower, with the ocean through which such sediments might be introduced. The existence of such openings or channels may be assumed from the forms of marine life which entered the inner water-areas where the cannel was formed. Furthermore, these interior shallows being the lowest parts of the marshy area, the waters draining into them from adjacent higher grounds would bring in more or less earthy matter. For these reasons it is hardly to be expected that cannel coal would yield a light ash. The smallest ash I have seen recorded is 2 per cent., while the largest may be 30 or 40 per cent., or even more. Many cannel coals are too earthy to be of any value.

I give some analyses of coal ashes made by Prof. Wormley.

	No. 1.		No. 2.	
	Per cent. of ash.	Per cent. of coal.	Per cent. of ash.	Per cent. of coal.
Silicic Acid,	49·10	1·645	37·40	0·2880
Iron Sesquioxide,	3·68	0·123	9·73	0·0749
Alumina,	38·60	1·293	40·77	0·3139
Lime,	4·53	0·152	6·27	0·0483
Magnesia,	0·16	0·005	1·60	0·0123
Potash and Soda,	1·10	0·037	1·29	0·0099
Phosphoric Acid,	2·23	0·075	0·51	0·0039
Sulphuric Acid,	0·07	0·002	1·99	0·0153
Sulphur (combined),	0·14	0·005	0·08	0·0006
Chlorine,	Trace.	Trace.	—	—
Total,	99·61	3·337	99·64	0·7670

No. 1. Ash from Youghiogheny coal, Western Pennsylvania.

No. 2. Ash from J. Sall's coal, Pigeon Creek, Jackson Co., Ohio.

In No. 2 the ash is very light, and nearly all of it may have been derived from the original vegetation. It contains more iron and sulphuric acid than No. 1 but much less phosphoric acid. In both cases the larger part is made up of silicic acid and alumina.

Sulphur in Coals.—This is a deleterious element found in all coals, not excepting the anthracites which have been subjected to a heating process sufficient to expel the bituminous portion. In bituminous coals it exists in different combinations. A part of it is combined with iron to form the bisulphide; a part passes off with the volatile hydrocarbons; a part remains with the fixed carbon of the coke, and a little remains in the ash. A sample of Youghiogheny coal analyzed by Prof. Wormley, gave a total sulphur of 0·98 per cent. Of this sulphur (only) 0·097 per cent. was combined with iron as a bisulphide; 0·223 per cent. passed off with the volatile matter in coking; 0·653 per cent. was found in the fixed carbon, and 0·007 per cent. remained in the ash.

So far as I know, chemists have not yet ascertained the exact nature of the combination made by the sulphur with the fixed carbon. Whether the sulphur combines with the carbon of the coke in any known form of sulphide would appear doubtful from the volatile character of such compounds, which would apparently necessitate their elimination in the process of coking. From the analysis above given, it is very obvious that the common notion that the sulphur in coals is in combination with iron, is quite a mistaken one. This is further illustrated by the following table of analyses, by Prof. Wormley, showing the per cent. of sulphur in several different coals with that of the iron, and also the proportion of sulphur that could have been combined with the iron.

Sulphur in coal, . .	0·57	1·18	0·98	2·00	0·91	0·86	0·51	0·74	4·04
Iron in coal, . .	0·075	0·742	0·086	0·425	0·122	0·052	0·102	0·102	2·05
Sulph. req. by the iron,	0·086	0·848	0·097	0·486	0·139	0·06	0·116	0·116	2·343

These facts are most interesting, and, as will be seen presently, have great practical importance.

While the proportion of sulphur of the bisulphide to the total sulphur in different coals are various, it will also be seen that the proportions of that which passes off with the gases are equally various. Among Prof. Wormley's analyses, I find the following:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7
Sulphur in coal, . .	0·49	0·93	0·91	0·68	0·57	0·56	0·98
Sulphur left in coke, .	0·082	0·015	0·007	0·30	0·43	0·46	0·66
Difference passing off in gases,	0·408	0·915	0·903	0·38	0·14	0·10	0·32

No. 1. Coal of lower bench of Straitsville (Ohio), seam.

No. 2. " middle " " " "

No. 3. " lower part of seam, J. Sells, Pigeon Creek, Jackson Co., Ohio.

No. 4. Coal of upper part of seam, J. Sells, Pigeon Creek, Jackson Co., Ohio.

No. 5. " Jackson Hill seam, Jackson Co., Ohio.

No. 6. " Briar Hill seam, Youngstown, Ohio.

No. 7. " Youghiogheny seam, Western Pennsylvania.

For gas-making, the less sulphur entering the gas the better, since it must all be removed by purification. For the blast furnace, the less sulphur remaining in the coke the better, for it is the sulphur in the coke which is injurious and not that in the volatile hydro-carbons, which pass off in the top of the furnace stack. In some cases, however, where the gas carries with it most of the sulphur, the gas may be so superior in illuminating power as to warrant its use, notwithstanding the increased cost of purification. For example, the average sulphur of the whole Straitsville seam, of eleven feet in thickness, is 0·792 per cent. Of this, 0·683 per cent. enters the gas, but the illuminating power being, on an average, eighteen candles, the gas is preferred to that made from the Youghiogheny coal, into which there enters only 0·32 per cent. of sulphur, but has an illuminating power of but fourteen candles.

In the evolving of gas from coals, a part of the volatile combustible matter condenses into tarry matters, and has to be deducted in our calculations from the total gaseous product, the remainder being the fixed or permanent gas. The difference between the whole volatile combustible product and the permanent gaseous product is often very considerable, and this difference varies in different varieties of coals. This subject has been so admirably set forth by Prof. Wormley, and is withal of so much practical importance, that I quote from him the following facts: "A coal which contained only 27·70 per cent. of volatile combustible matter evolved 3·82 cubic feet of fixed gas per pound, whilst another, which contained 38·80 per cent of volatile combustible matter, evolved only 3·03 cubic feet per pound." Of fourteen samples tested, the average volatile combustible matter was 33·54 per cent., and that of the permanent gas in cubic feet per pound of coal was 3·306. Gas works practically obtain more gas per pound than the chemist, doubtless through a re-distillation of a part of the tarry matter. Prof. Wormley also suggests that at such works the measurement is taken at a higher temperature, a difference of five degrees changing the volume of gas about one per cent. "From a fair average of Youghiogheny coal," Prof. Wormley "obtains only about 3½ cubic feet per lb., whereas, in the ordinary manufacture of illuminating gas, this coal, as is well known, yields about four cubic feet per lb. of coal."

The sulphur in coals is derived from two sources, viz., from the vegetable itself and from the water of the ocean. Bischof states that "the ash of beechwood contains as much sulphuric acid and peroxide of iron as would suffice to form iron pyrites amounting to $\frac{1}{1807}$ of the weight of the wood. The peroxide of iron would yield 23 times as much pyrites if sulphates were brought in contact with it from outwards. Fir wood can give rise to the formation of ten times as much iron pyrites as beech wood." The large amount of carbonaceous matter of the coal vegetation acting upon the alkaline and earthy sulphates in the sea water, would, with the aid of proto carbonate of iron, form more or less pyrites, and Bischof asserts that it is actually formed in this way. He, however, limits the action upon sulphates, as far as it goes on in the sea, to the decomposition of sulphate of lime. But these chemical reactions only explain so much of the sulphur as is combined with iron as pyrites or bisulphide. It is barely possible that so large a body of decomposing vegetable matter might set free more sulphuric acid from the sulphates than there was iron to combine with, and the excess, probably losing its oxygen, went to form new combinations with the organic matter of the decomposing vegetation.

It is impossible to assign a reason why one coal should contain more sulphur than another. If it came exclusively from the inorganic part of the vegetation itself, it is easy to see, as in the case of the ash already discussed, that the more extensive and longer continued the decay of the vegetation, the larger the accumulation of sulphur in the final residuum of coal; but doubtless only a small part came in this way.

The sulphate being always present in sea water and probably in uniform quantities, and there always being iron enough in the water, —certainly in the era of the lower Coal Measures of Ohio, where the iron is everywhere precipitated as a carbonate of the protoxide or siderite,—we should naturally expect from uniform conditions uniform results. But in fact no two seams of coal contain the same amount of sulphur, and the same seam shows not only in different locations very different amounts, but also in different parts in its vertical range at the same location.

Rapidity of formation of Coal.—It is probable that the buried vegetation passed through its changes and became hard and perfect coal in a much shorter time than is generally supposed. In Perry county, Ohio, I found near the base of a sand rock over the Nelsonville or Straitsville seam of coal a perfect bowlder of coal, a flattened disk

nearly four inches in diameter and two and a half inches deep. It was found about thirteen feet above the seam of coal, there being in the interval a foot of sand rock and twelve feet of shales, sandy at top and clayey at bottom. The bowlder is a fragment torn from some seam of coal and rounded by attrition in the moving waters which brought in the sand of the sand rock. The structure of the coal appears to be that of the Straitsville seam. This seam, at a location a few miles from the place where the bowlder was found, has, over a limited area, been violently torn away by waves or some powerful current of water, and the excavation filled with mud, now forming an unstratified mass of clay. As it is barely possible that the excavation extended downward in deep water to a considerable depth to any of the lower or older seams, we may perhaps infer that the bowlder came from the Straitsville seam at that spot. The direction—a little east of north—is the one in which the waters of the ocean of that period would be most likely to carry debris shoreward. We have, then, the apparent proof that the vegetation became hard and perfect coal after its burial in time to furnish bowlders now found in the coarse sand rock only thirteen feet above it. In other words, the time for the accumulation of twelve feet of shales added to whatever interval there might have been before the incoming of the sand, was long enough for the perfecting of the coal. This time is very indefinite, of course, but measured by stratigraphical accumulations, somewhat after the manner of Prof. Dana's time-ratios, it is geologically very short. In Wayne county, West Virginia, I found near the bottom of a very coarse sand-rock, and separated by about ten feet of bituminous shales, upon a thin seam of coal, quite a mass of angular fragments of coal. Some of the fragments were worn the merest trifle, but most were angular and some were sharply wedge-shaped. It is impossible to believe that fragments of so tender a material could have been subjected to the attrition of the coarse sand, with which they were transported, and in which they are now imbedded, for any considerable distance. Hence they were torn from some seam of coal not far away. It is, moreover, unreasonable to suppose that the cavity of excavation could have extended far down to the lowest and oldest coals, from the fact stated in the other case, that the work of such excavation must have taken place below the surface of the water, the last formed seam being at the time at least ten or twelve feet below that surface. If the coal came from the seam first below, it is reasonable to infer that the vegetation of the seam had passed through the process of bituminization and final solidification during the interval between the time of

the burial by sediments of the coal-marsh and the filling in of ten or twelve feet of intervening materials. The only other possible explanation of these facts, occurring to my mind, is, that some portion of the area of the lower Coal Measures had been raised above its proper place beneath the waters, and either constituted headlands from which the waters of the ocean could tear away the fragments of coal and transport them to their present location, or formed highlands from which rivers might have brought down the coal debris. So far as my observations go, there is not a shadow of proof of any such upheaval during the progress of the formation of our coal seams, but, on the other hand, all observed facts militate against such a supposition.

I have observed another class of facts which have interested me much, and which may have a bearing upon the comparatively rapid bituminization and solidification of the coal. Over considerable horizontal areas I have sometimes found the coal planed off as if it had already become a solid substance. For example, on Sunday Creek, Perry county, Ohio, I find the thick, or eleven feet, seam of coal—the Nelsonville or Straitsville seam—eroded in various places and in varying depths from the top. Sometimes it is planed or ground away to the depth of a foot; sometimes the whole upper bench is gone, and again the erosion has taken away the upper and part of the middle benches. Then several benches are always seen in great distinctness in the seam in its normal development, being separated by the partings of slate. In all cases the sandrock fills the space once occupied by the coal, and rests unconformably upon the eroded edges of the laminæ of the coal. The usual cover of the coal is shales, sometimes twenty feet or more thick, and there is every reason to believe that such shales were first deposited over the coal at the eroded places. At some subsequent time and after the vegetation had become coal, currents of water carried away the softer shales and perhaps, by the aid of moving sand, planed off the upper portion of the coal-seam. This has been done in a smooth and even manner, and there are no traces of the kind of rough work which the same force would have performed if the material acted on was a mass of soft and unconsolidated decomposed vegetable matter. In another coal-seam which I traced for miles in West Virginia, the upper part of the original seam had almost everywhere been planed off by a force which left over the coal coarse sand, now hardened into sandrock. In some places I found the remnants of the original top of the seam with shale over them. It appeared evident that the sandrock was not the first cover of the coal vegetation. No plants or fragments of trees such as often

show themselves in the roof of coal seams could anywhere be found in it. In the concavities in the under surface of the rock, I have found the coal which filled them preserving its horizontal lamination and not curved, or only slightly so, to fit the shape of the rock surface. Apparently the top of the coal seam, after it had become a comparatively solid body, had been removed, and the sand which covered it adjusted itself to the little irregularities of the surface of the coal. The interval between the time when the vegetable matter was first accumulated and the time when its first covering of shale was removed, and the sands brought in, might have been very great, but relatively to the time of the accumulation of the whole Coal Measures, it was very brief.

I have time, in conclusion, to notice only one or two matters of practical importance in the use of our bituminous coals. The vast quantity of excellent iron ore in our land, with a corresponding amount of excellent fuel for smelting it, points to this country as one destined to become the leading nation in iron manufactures. In this industry our bituminous coals are already beginning to play an important part. The prerequisites for a good furnace coal are—if we use the raw or uncoked coal—a dry or open burning quality, little sulphur, small ash, sufficient fixed carbon and firmness of coke. If coke and not raw coal be used, it should be firm and capable of resisting pressure, and contain as small per centage of sulphur and ash as possible. Sulphur in coal is a prime difficulty, but this is becoming better and better understood by iron manufacturers. Of late years attempts have been made with greater or less success, to separate the sulphur from coal by a somewhat mechanical process, viz., by crushing the coal and floating off by water the lighter and purer portions, which are saved and afterward converted into coke. The rest, composed of the coal charged heavily with bi-sulphide of iron and of the slate, is thrown away. When, however, the sulphur is not combined with iron as a bi-sulphide, but is in other combinations as has already been shown, this mechanical process must fail, and even when, as is often the case, the bi-sulphide is disseminated evenly through the whole mass of the coal, and is not in a segregated condition in the form of laminæ, discs, etc., there will also be a failure in the separation. The sulphur may be combined with the lightest and apparently purest portion of the coal, if quality is to be determined by specific gravity. For illustration, I give the analysis of a coal which appeared in every way promising, and contained no visible bi-sulphide of iron.

There was found by Prof. Wormley 0·39 per cent. of iron. This

iron would require 0·445 per cent. of sulphur to form the usual bisulphide. Besides this amount, there remained in the coal 2·885 per cent. of sulphur. This large amount of sulphur could not be removed by any washing process, since it is disseminated through the whole mass of the coal. If the purification of coal is therefore to be attempted by discriminating by a mechanical process, in the relative specific gravities, the method will only be successful where the sulphur is in the form of a bisulphide of iron, and this is in a segregated form.

Another important point to be determined in the use of bituminous coal for iron-making is the physical character of the coke. If raw coal is used, it is speedily converted into coke in the top of the furnace, and descends as such to the bottom, where it is consumed, and the chief heat produced; while in the bottom there rests upon it and upon the other materials which have descended with it the burden of the whole vertical column of the contents of the furnace directly above. The coke, therefore, should be firm and solid to hold up the superincumbent mass. If it is, on the other hand, tender and crushes under the weight, it becomes compacted together, the blast does not penetrate it, and a slow and imperfect combustion is the result. From such impeded combustion many and great evils arise which are familiar to all intelligent iron masters. To this cause, more than to any other, is to be attributed the "bad working" of so many furnaces using tender fuels. The firmest cokes are made from the more highly bituminous or coking coals, such as melt and swell when heated, and after the bituminous gases are driven off, leave a hard, porous, cinder-like mass, which has a metallic lustre and an almost metallic ring when struck. Such coke, either cold or hot, is broken with difficulty, and will resist great pressure without crushing. The best known English coke of this type is made from the North Durham coal. It is the strength and firmness of this coke that renders the very high furnaces of the Cleveland Iron District possible. The coke made from a similar highly cementing coal at Connelsville, Pa., has a somewhat similar firm and obdurate quality. All cokes made from the soft and caking coals have a tendeney to be more or less firm from the fact that such coals soften and melt when heated. The best coke comes from the most thorough fusion of the coal. On the other hand, the dry and open burning coals show a very different behavior in the fire. They do not melt and swell, and consequently change but slightly their original form. A block of such coal parts with its bituminous gases through cracks, which more generally open along the planes of